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Introduction

History

The history of magnetism began with the discovery of the properties of a mineral called magnetite (Fe_3O_4). The most plentiful deposits were found in the district of Magnesia in Asia Minor (hence the mineral's name) where it was observed, centuries before the birth of Christ, that these naturally occurring stones would attract iron. Later on it found application in the lodestone of early navigators. In 1600 William Gilbert published *De Magnete*, the first scientific study on magnetism. In 1819 Hans Christian Oersted observed that an electric current in a wire affected a magnetic compass needle, thus with later contributions by Faraday, Maxwell, Hertz and others, the new science of electromagnetism came into being.

Even though the existence of naturally occurring magnetite, a weak type of hard ferrite, had been known since antiquity, producing an analogous soft magnetic material in the laboratory proved elusive. Research on magnetic oxides was going on concurrently during the 1930's, primarily in Japan and the Netherlands. However, it was not until 1945 that J. L. Snoek of the Philips' Research Laboratories in the Netherlands succeeded in producing a soft ferrite* material for commercial applications.

Fair-Rite Products Corp. was not far behind in the manufacture and sale of soft ferrites for use in the electronics industry. It was formed in 1952 and officially started operations in 1953. The ensuing years have seen a rather crude product, which was available in only a few shapes and materials, develop into a major line of ferrite components for inductive devices, produced in many core configurations with a wide selection of materials. The application of ferrites in EMI suppression as shield beads and broadband chokes, where an effective resistive impedance is produced at high frequencies, has grown so fast in the last decade, that their use as EMI suppressors is limited only by the imagination of the end user.

Soft Ferrites

The single most important characteristic of soft ferrites, as compared to other magnetic materials, is the high volume resistivity exhibited in the monolithic form. Since eddy current losses are inversely proportional to resistivity and these losses increase with the square of the frequency, high resistivity becomes an essential factor in magnetic materials intended for high frequency operation. The magnetic properties of ferrite components are isotropic, and by employing various pressing, extruding, and/or grinding techniques, a wide range of complex shapes can be formed. There is no other class of magnetic material that can match soft ferrites in performance, cost and volumetric efficiency, over the range from audio frequencies to above 200 MHz.

During the last 25 years the basic constituents of ferrites have changed little, but purity of raw materials and process control have improved dramatically. Ferrites are ceramic materials with the general chemical formula $\text{MO} \cdot \text{Fe}_2\text{O}_3$, where MO is a divalent metal oxide blended with 48 to 60 mole percent of iron oxide. Fair-Rite manufactures three broad groups of soft ferrite materials:

Manganese zinc (Fair-Rite 33, 73, 75, 76, 77 and 78 material)

Nickel zinc (Fair-Rite 42, 43, 44, 61, 65, 67 and 68 material)

Manganese (Fair-Rite 85 material)

Manganese zinc ferrites are completely vitrified and have very low porosity. They have the highest permeabilities and exhibit volume resistivities ranging from one hundred to several thousand ohm-centimeter. Manganese zinc ferrite components are used in tuned circuits and magnetic power designs from the low kilohertz range into the broadcast spectrum. These ferrites have a linear expansion coefficient of approximately 10 ppm/ $^{\circ}\text{C}$.

The nickel zinc ferrites vary in porosity, and frequently contain oxides of other metals, such as those of magnesium, manganese, copper or cobalt. Volume resistivities range from several kilohm-centimeter to tens of megohm-centimeter. In general, they are used at higher frequencies (above 1 MHz), and are suitable for low flux density applications. Nickel zinc ferrites have a linear expansion coefficient of approximately 8 ppm/ $^{\circ}\text{C}$.

The manganese ferrite is a dense, temperature stable material displaying a high degree of squareness in its hysteresis loop. This makes this material uniquely suited for such applications as multiple output control in switched-mode power supplies and high frequency magnetic amplifiers.

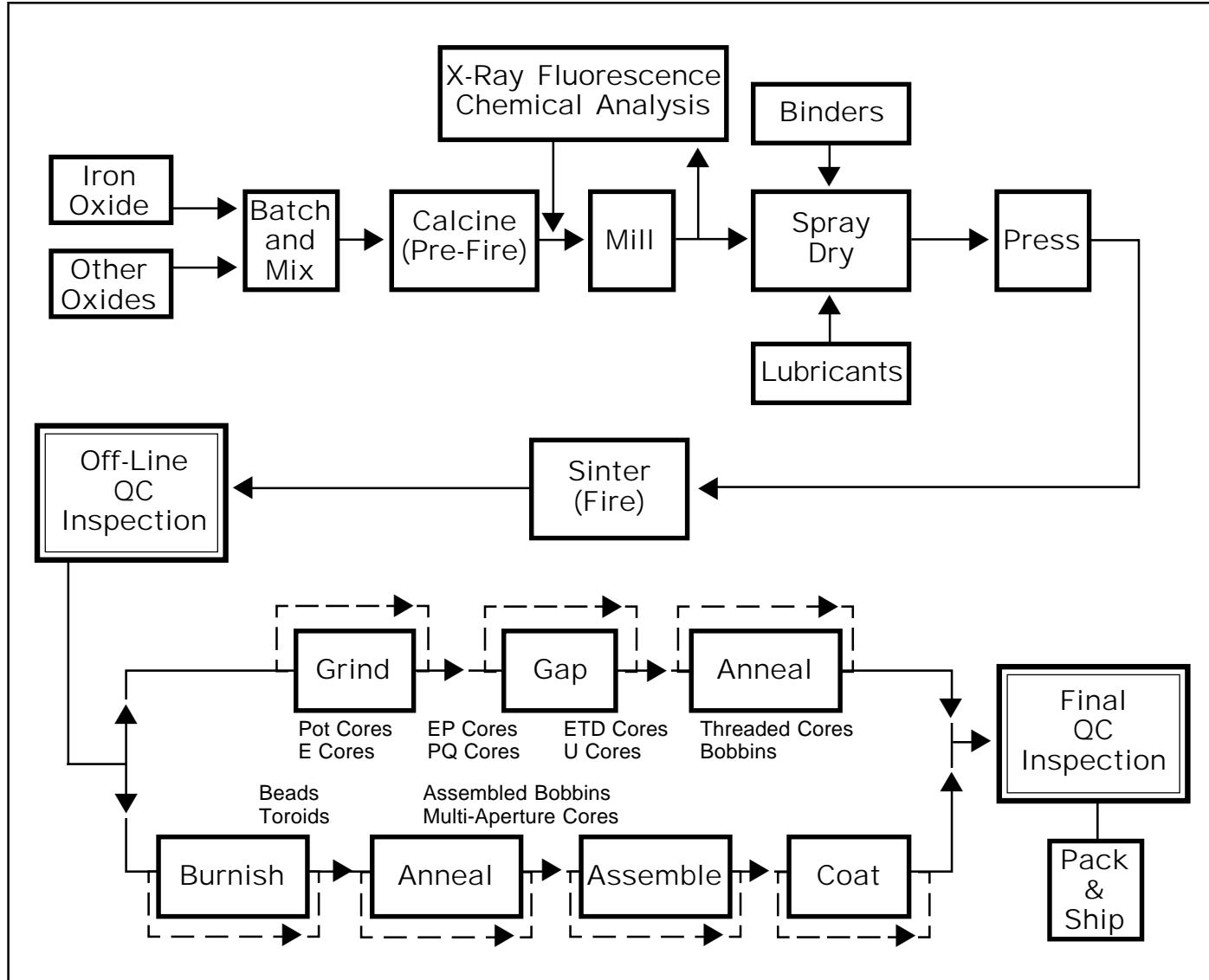
As is evident from the flow diagram on page 3, there is considerable processing involved, and the manufacturing cycle will take a minimum of two weeks. The parts listed in the catalog represent a broad cross section of the wide variety of cores produced by Fair-Rite Products. Large OEM quantities are manufactured by Fair-Rite to order. Most of the more commonly used parts are stocked by our distributors, offering prompt deliveries. For a complete listing of our distributors see the back cover of the catalog.

Many of the parts produced by Fair-Rite are made to customer specifications, and we welcome inquiries involving application-specific designs. We have the capability to design tooling rapidly, and have it fabricated either by our own tool shop or by outside vendors.

*Footnote: The difference between hard and soft ferrite is not tactile, but rather a magnetic characteristic. Soft ferrite does not retain significant magnetization, whereas hard ferrite magnetization is considered permanent.

Introduction

Simplified Process Flow Diagram



Fair-Rite Products Corp.
CAGE # 34899
Federal ID# 141389596

Ferrite Cores
Standard Industrial
Classification (SIC) 3264

Magnetic Properties of

Property	Unit	Symbol	68	67	65	61	44
Initial Permeability @ B <10 gauss		μ_i	20	40	100	125	500
Flux Density @ Field Strength	gauss mT oersted A/m	B H	2000 200 40 3200	3000 300 20 1600	2150 215 10 800	2350 235 10 800	3000 300 10 800
Residual Flux Density	gauss mT	B_r	1000 100	1000 100	1300 130	1200 120	1100 110
Coercive Force	oersted A/m	H_c	10 800	3.0 240	2.35 188	1.6 128	.35 28
Loss Factor @ Frequency	10^{-6} MHz	$\tan \delta/\mu_i$	400 100	150 50	80 7.9	32 2.5	85 1.0
Temperature Coefficient of Initial Permeability (20-70 °C)	%/°C		.06	.13	.05	.15	—
Curie Temperature	°C	T_c	>500	>475	>400	>350	>160
Resistivity	Ω cm	ρ	10^7	10^7	10^7	10^8	10^9
Power Loss Density 25kHz - 2000 G - 100°C 100kHz - 1000 G - 100°C	mW/cm ³	P	— —	— —	— —	— —	— —
Recommended Frequency Range	MHz						
Application Areas	L E P S		<400 — — —	<300 — — —	<125 — — —	<100 >200 — —	— 30-250 — —
See this page for additional material data			7	8	9	10	12

Application Areas
 L Low flux density devices.
 E EMI suppression.
 P Power magnetics.
 S Special square loop ferrite.

Additional ferrite mechanical and thermal characteristics are tabulated on page 6.

Fair-Rite Materials

33	43	85*	77	78	73	75	76
800	850	900	2000	2300	2500	5000	10000
2500	2750	3900	4600	5000	4000	3900	4000
250	275	390	460	500	400	390	400
10	10	10	10	37.5	10	10	2
800	800	800	800	3000	800	800	160
1350	1200	3400	1150	1500	1000	1250	1250
135	120	340	115	150	100	125	125
.30	.30	.50	.22	.20	.18	.16	.10
24	24	40	17.5	16	14.5	13	8
35	120	50	4.5	4.5	7	15	15
.2	1.0	.1	.1	.1	.1	.1	.025
.1	1.0	—	.6	1.2	.8	.9	.9
>150	>130	>200	>200	>200	>160	>140	>120
10 ²	10 ⁵	2 10 ²	10 ²	2 10 ²	10 ²	3 10 ²	50
—	—	—	200	<115 <130	—	140	—
—	—	—	—	—	—	—	—
<3	<10 30-200	—	<3 <30 <.1 <.15	<2.5 — <.5 —	<2.5 <30 — —	<.75 <15 <.1 —	<.5 — — —
13	14	11	16 & 17	18 & 19	15	20	21

42 Material, specifically developed for absorber applications in Anechoic Chambers, is listed on page 89.

* New Fair-Rite material, added in this edition of the catalog.

Material Characteristics

Ferrite Material Constants

Specific Heat	25 cal/g/°C
Thermal Conductivity	10x10 ⁻³ cal/sec/cm/°C
Coefficient of Linear Expansion	8 - 10x10 ⁻⁶ /°C
Tensile Strength	4.9 kgf/mm ²
Compressive Strength	42 kgf/mm ²
Young Modulus	1.3 kgf/mm ²
Hardness (Knoop)	650
Specific Gravity	≈ 4.7 g/cm ³

The above quoted properties are typical for Fair-Rite MnZn and NiZn ferrites.

Properties of Parylene C* Coating Material

Dielectric Strength5600	V/mil
Volume Resistivity	8.8 10 ¹⁶	ohm
Surface Resistivity	10 ¹⁴	ohm
Dielectric Constant (1MHz)	2.95	
Dissipation Factor (1MHz)013	
Density	1.29	g/cm ³
Water Absorption (24 hrs)	<1	%
Coefficient of Friction29	
Continuous Operating Temperature	<100	°C
Thermal Conductivity	2.0 10 ⁻⁴	cal/sec/cm/°C

* Union Carbide Trademark

Conversion Table

SI Units	CGS Units
1 T (tesla) = 1 Vs/m ²	= 10 ⁴ gauss
1 mT	= 10 gauss
1 A/m = 10 ⁻² A/cm	= .0125 oersted
.1 mT	= 1 gauss
80 A/m	= 1 oersted

Greek Alphabet

A, α	Alpha	N, ν	Nu
B, β	Beta	Ξ, ξ	Xi
Γ, γ	Gamma	O, ο	Omicron
Δ, δ	Delta	Π, π	Pi
E, ε	Epsilon	Ρ, ρ	Rho
Z, ζ	Zeta	Σ, σ	Sigma
H, η	Eta	Τ, τ	Tau
Θ, θ	Theta	Υ, υ	Upsilon
I, ι	Iota	Φ, φ	Phi
K, κ	Kappa	Χ, χ	Chi
Λ, λ	Lambda	Ψ, ψ	Psi
M, μ	Mu	Ω, ω	Omega

68 Material

Primary Characteristics

Frequency range up to 400 MHz
High Q
Excellent temperature stability from -50° to 300° C
High resistivity

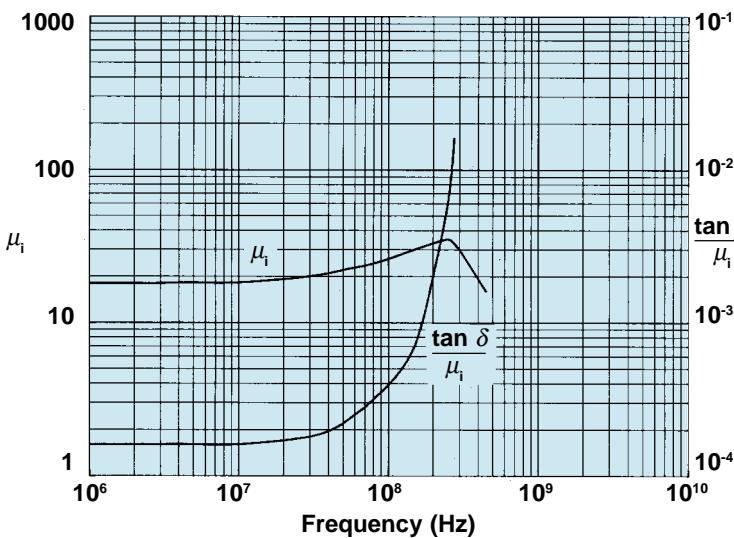
Applications

HF coils and matching transformers
Antennas
Broadband transformers

Available Core Shapes

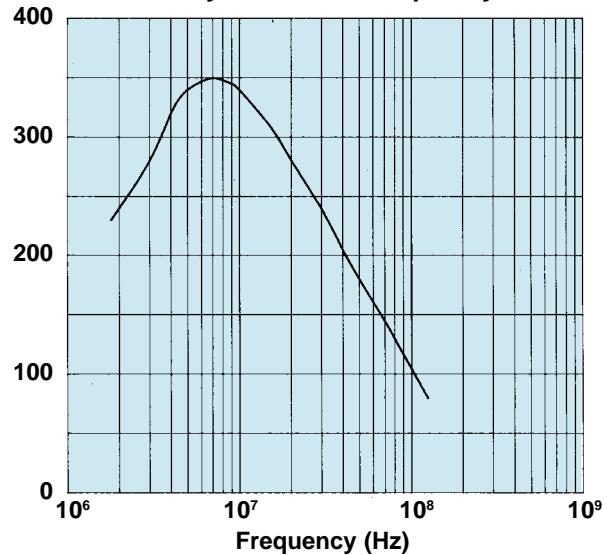
Toroids, slugs, multi-aperture cores

Initial Permeability & Loss Factor vs. Frequency



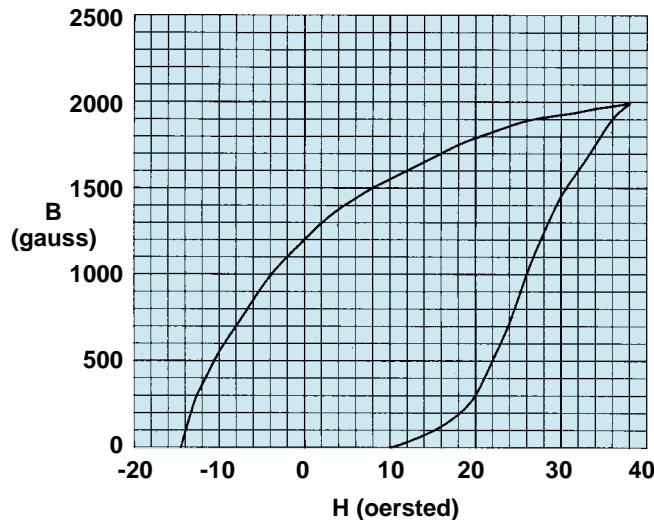
Measured on a **9.5mm** OD toroid using HP 4275A and HP 4191A.

Quality Factor vs. Frequency



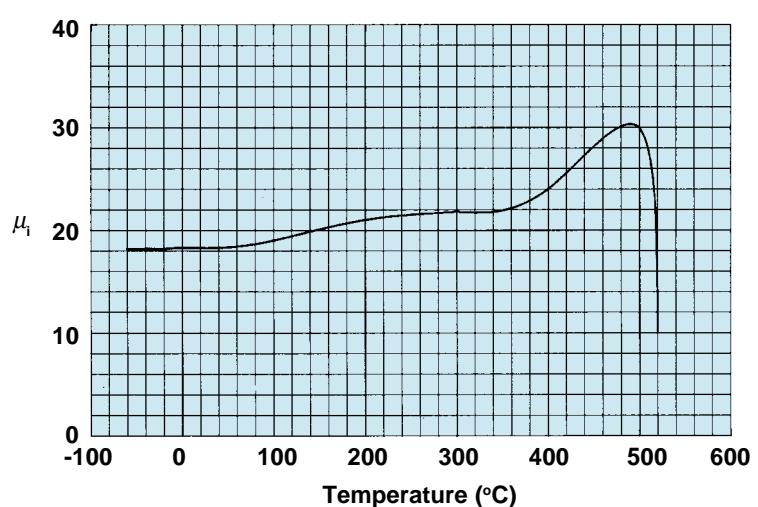
Measured on a **9.5mm** OD toroid using HP 4275A and HP 4191A.

Hysteresis Loop



Measured on a **25.4mm** OD toroid.
If material has been saturated it will exhibit a higher initial permeability, a lower Q and the hysteresis curve will assume a different shape.

Initial Permeability vs. Temperature



Measured on a **9.5mm** OD toroid at 100 kHz using a HP 4275A.

67 Material

Primary Characteristics

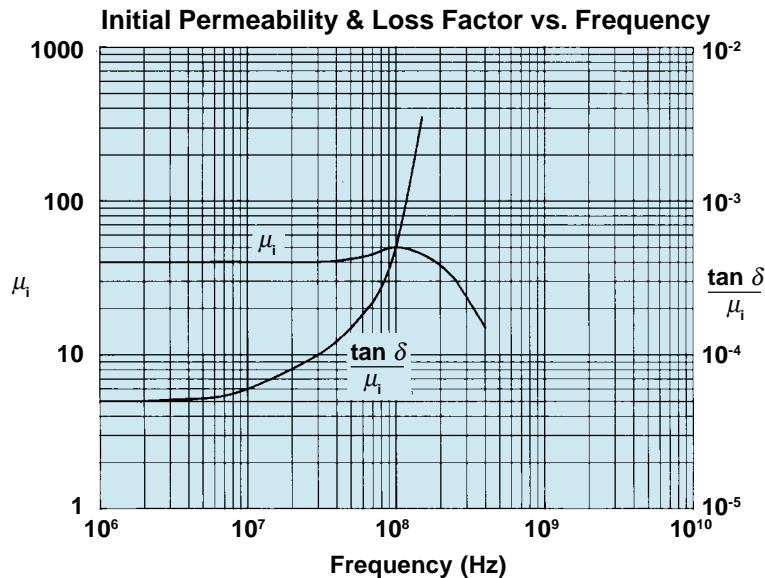
Frequency range up to 300 MHz
High Q
Excellent temperature stability from -50° to 300° C
High resistivity

Applications

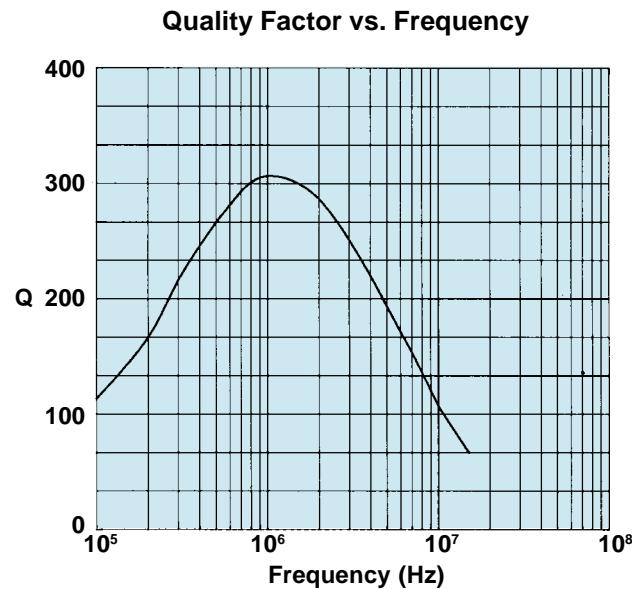
Antennas and high frequency coils
Broadband and linear power transformers

Available Core Shapes

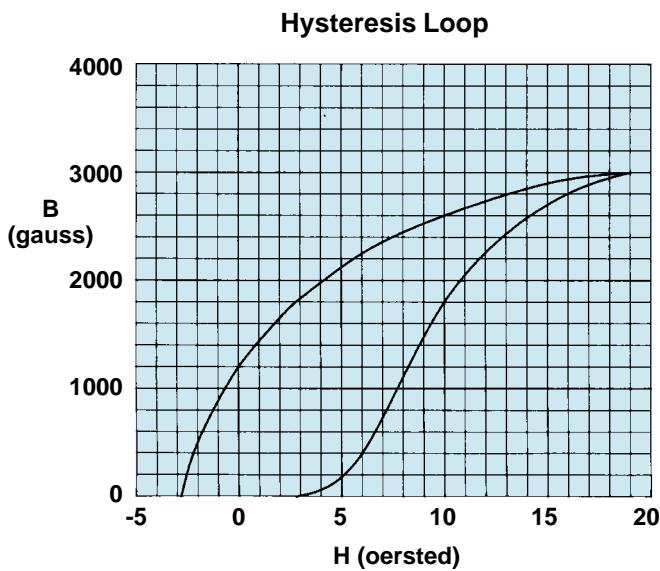
Toroids, slugs, multi-aperture cores



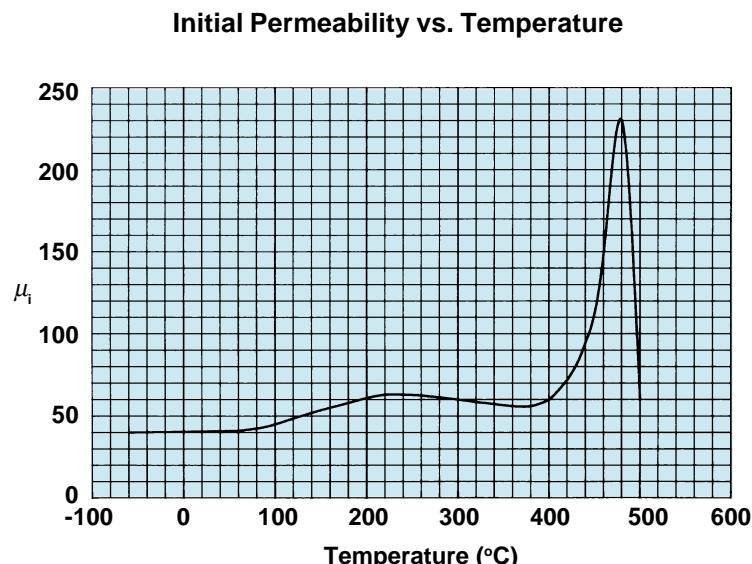
Measured on a 9.5mm OD toroid using HP 4275A and HP 4191A.



Measured on a 9.5mm OD toroid using HP 4275A and HP 4191A.



Measured on a 25.4mm OD toroid.
If material has been saturated it will exhibit a higher initial permeability, a lower Q and the hysteresis curve will assume a different shape.



Measured on a 9.5mm OD toroid at 100 kHz using a HP 4275A.

65 Material

Primary Characteristics

Frequency range up to 125 MHz

High Q

Excellent temperature stability from

room temperature to 125° C

High resistivity

Applications

HF broadband and coupling transformers

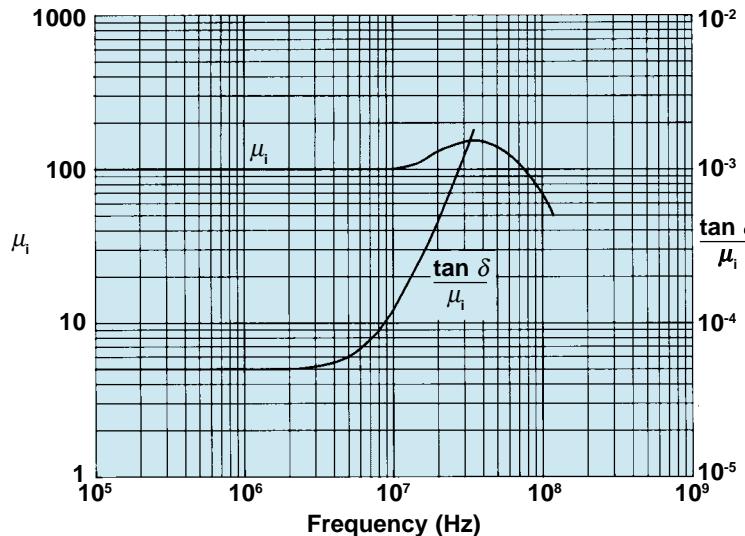
Balun transformer designs

Available Core Shapes

Multi-aperture cores

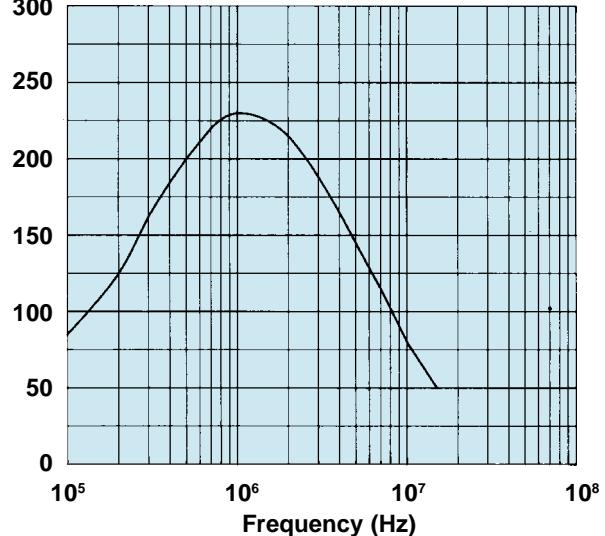
Note: This material is not recommended for new designs.

Initial Permeability & Loss Factor vs. Frequency



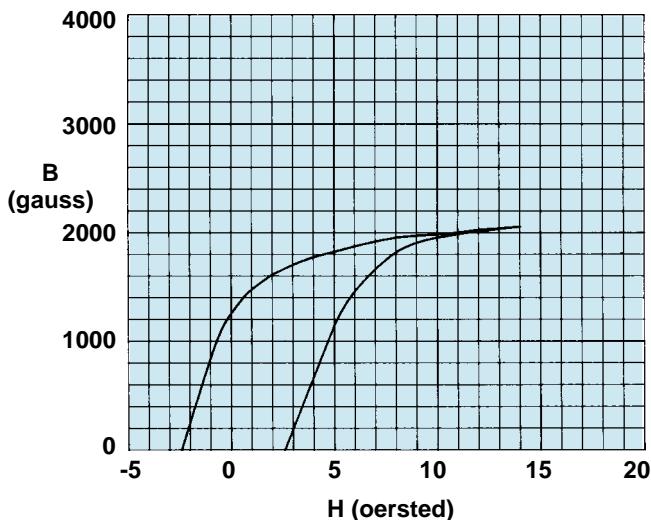
Measured on a 25.4mm OD toroid using HP 4275A and HP 4191A.

Quality Factor vs. Frequency



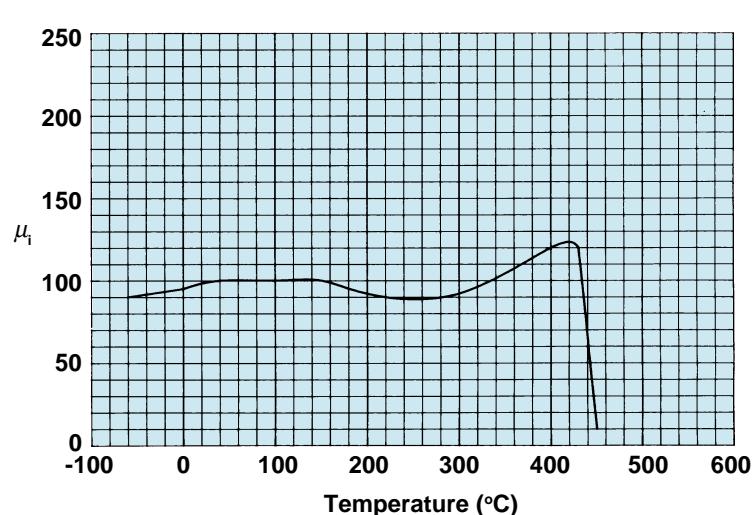
Measured on a 25.4mm OD toroid using HP 4275A and HP 4191A.

Hysteresis Loop



Measured on a 25.4mm OD toroid.

Initial Permeability vs. Temperature



Measured on a 25.4mm OD toroid at 100 KHz using a HP 4275A.

61 Material

Primary Characteristics

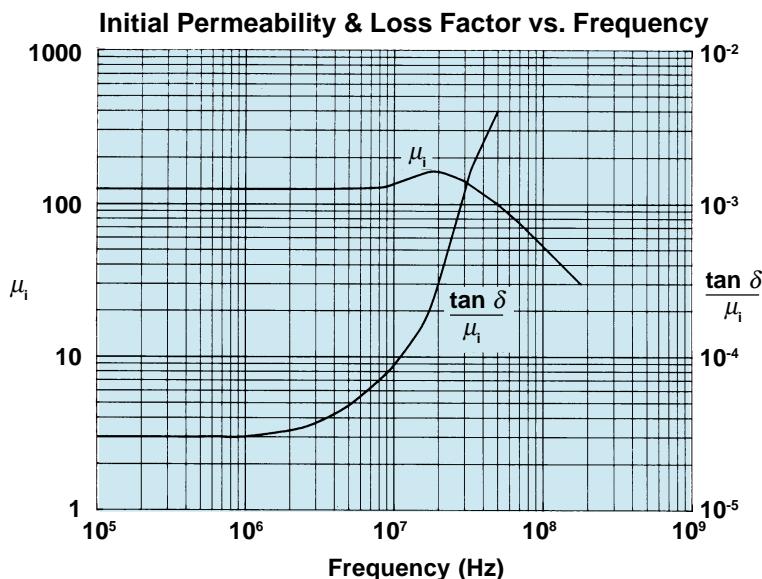
Frequency range up to 100 MHz
High Q
Tuned frequency applications up to 10 MHz
High resistivity

Applications

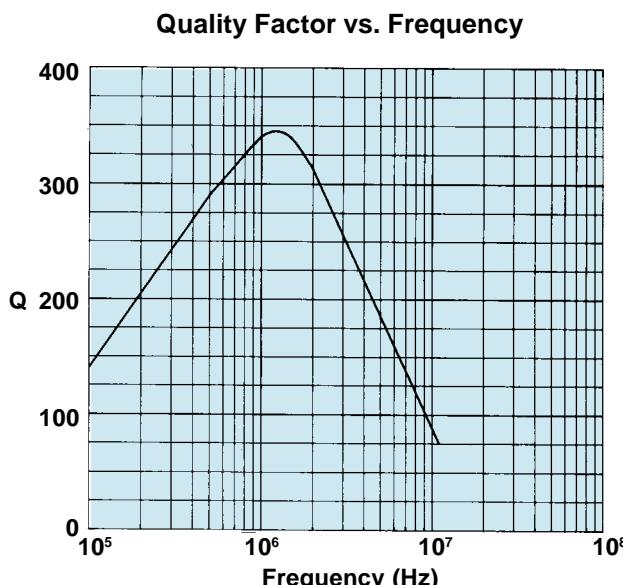
Antennas
Inductors, choke coils and broadband transformers
EMI suppression for frequencies > 200 MHz.

Available Core Shapes

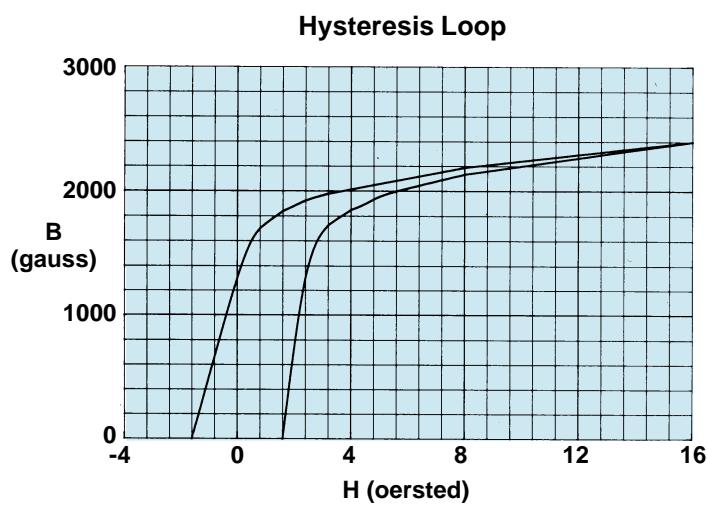
Slugs, toroids, shield beads, wound beads, beads on leads, multi-aperture cores



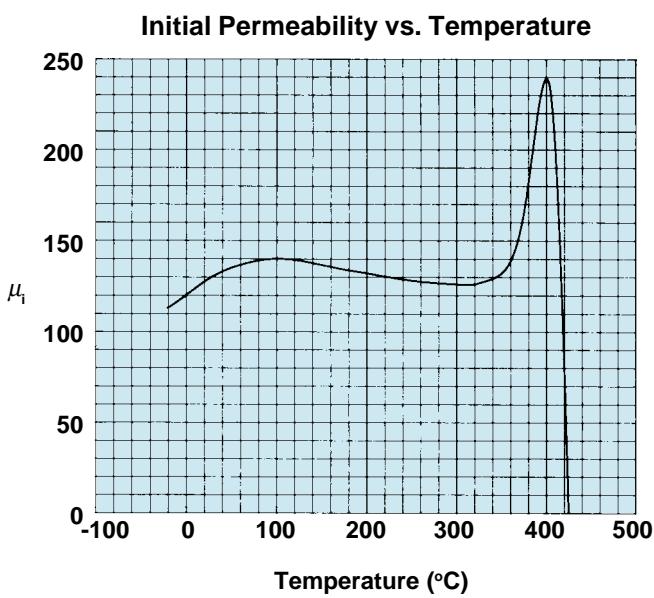
Measured on a 25.4mm OD toroid using HP 4275A and HP 4191A.



Measured on a 25.4mm OD toroid using HP 4275A and HP 4191A.



Measured on a 25.4mm OD toroid.



Measured on a 25.4mm OD toroid at 100 kHz using a HP 4275A.

85 Material

Primary Characteristics

Square hysteresis loop over a wide temperature range
 Squareness ratio $B_r/B > 0.85$ at 23°C
 Curie temperature > 200°C

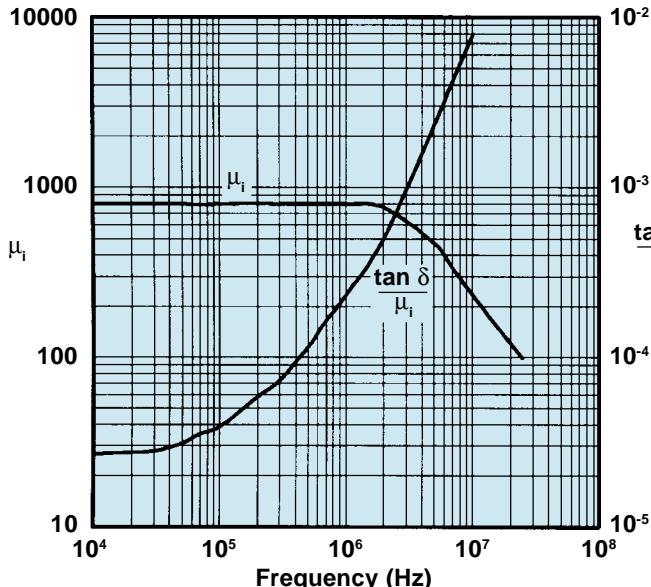
Applications

Converters and inverters
 Output regulators for switch-mode power supplies
 Spike Suppression

Available Core Shapes

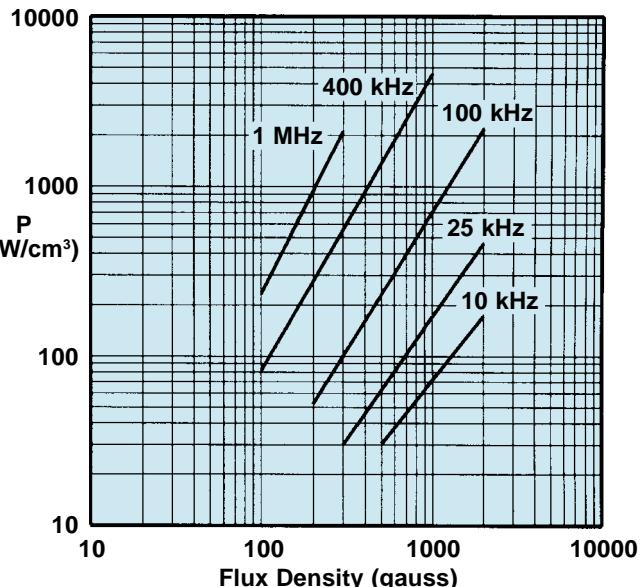
Toroids

Initial Permeability & Loss Factor vs. Frequency



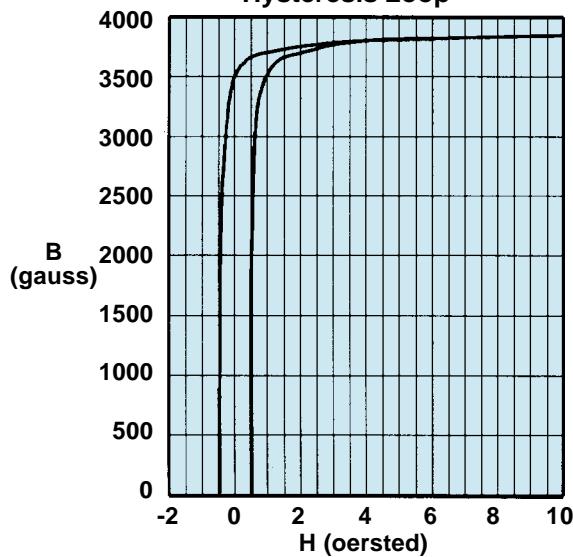
Measured on a 13mm OD toroid using HP 4284A and HP 4285A

Power Loss vs. Flux Density



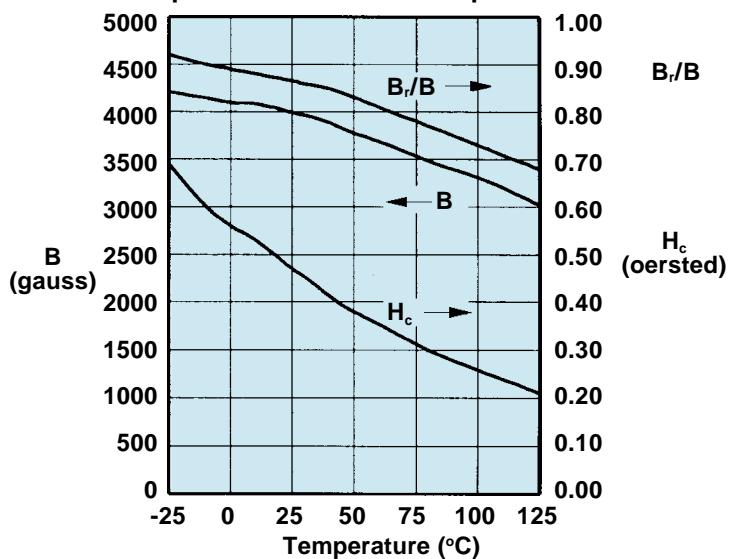
Measured on a 13mm OD toroid using a Clarke-Hess 258 VAW.

Hysteresis Loop



Measured on a 13mm OD toroid.

Flux Density, Coercive Force and Squareness Ratio vs. Temperature



Measured on a 13mm OD toroid, B is measured at $H=10$ oersted.

44 Material

Primary Characteristics

High impedance
Very high volume resistivity

Applications

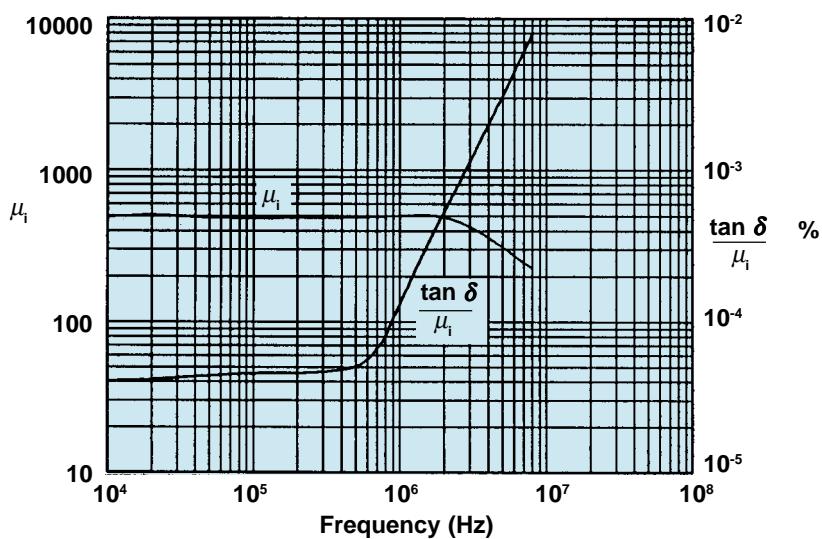
Designs which require a very high ferrite resistivity. Typical applications are when copper conductors make contact with the ferrite material, eg in connector suppression plates.

Suppression material for use over the 25 to 200 MHz frequency range.

Available Core Shapes

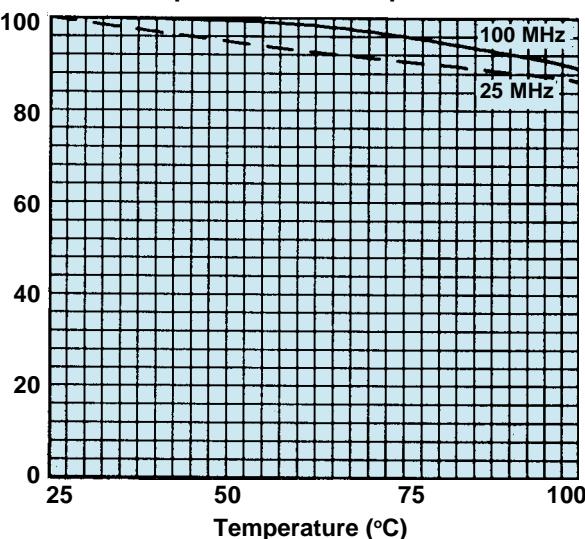
Round cable suppression cores, SM beads,
connector suppression plates

Initial Permeability & Loss Factor vs. Frequency



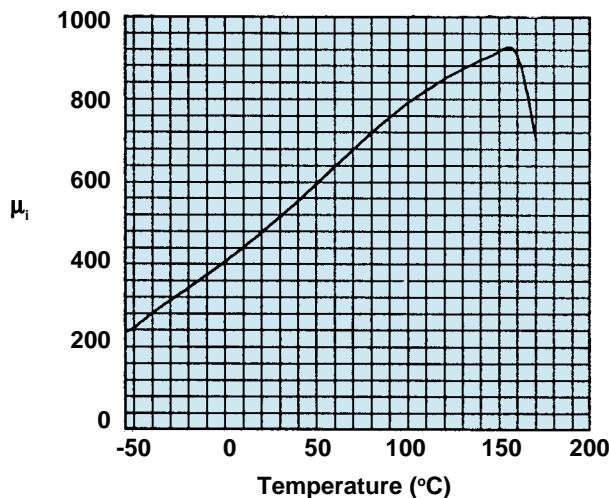
Measured on a 25.4mm OD toroid using HP 4275A.

Percent of Original 25°C Impedance vs. Temperature



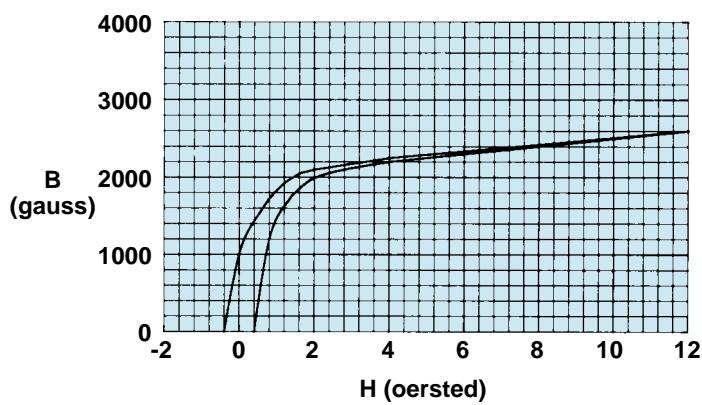
Measured on a 30mm OD toroid using a HP 4193A.

Initial Permeability vs. Temperature



Measured on a 30mm OD toroid at 100 kHz using a HP 4275A.

Hysteresis Loop



Measured on a 25.4mm OD toroid at 10 kHz.

Fair-Rite Products Corp.

Phone: (888) FAIR RITE / (914) 895-2055 • FAX: (888) FERRITE / (914) 895-2629 • www.fair-rite.com • E-Mail: [\(888\) 324-7748](mailto:ferrites@fair-rite.com)

One Commercial Row, Wallkill, NY 12589-0288

(888) 337-7483

33 Material

Primary Characteristics

Frequency range up to 3 MHz
Medium permeability
Good temperature stability

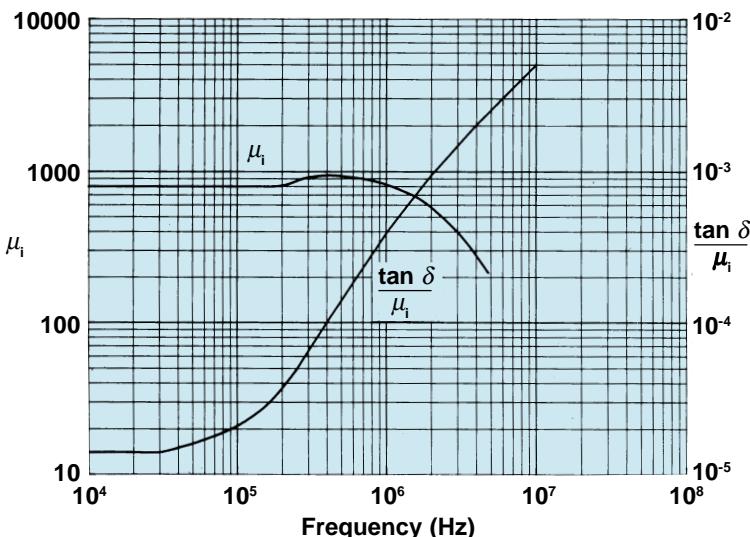
Applications

Inductors at medium frequency.

Available Core Shapes

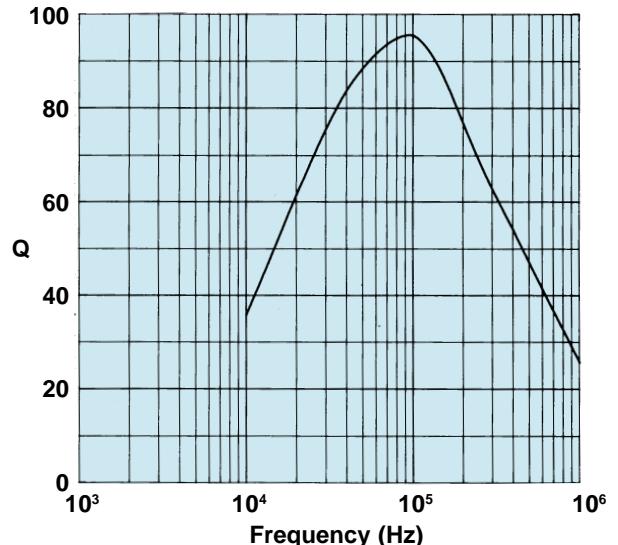
Slugs

Initial Permeability & Loss Factor vs. Frequency



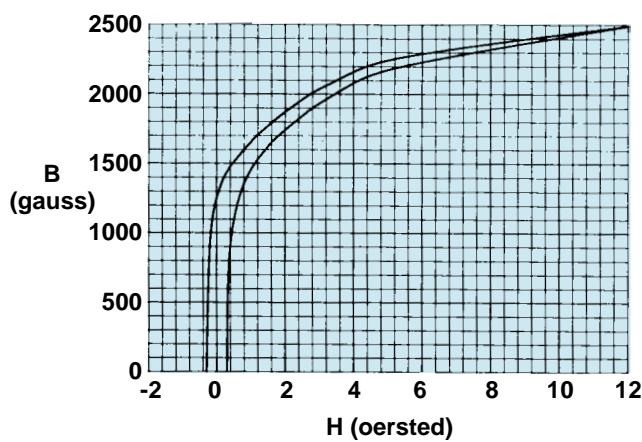
Measured on a 25.4mm OD toroid using HP 4275A.

Quality Factor vs. Frequency



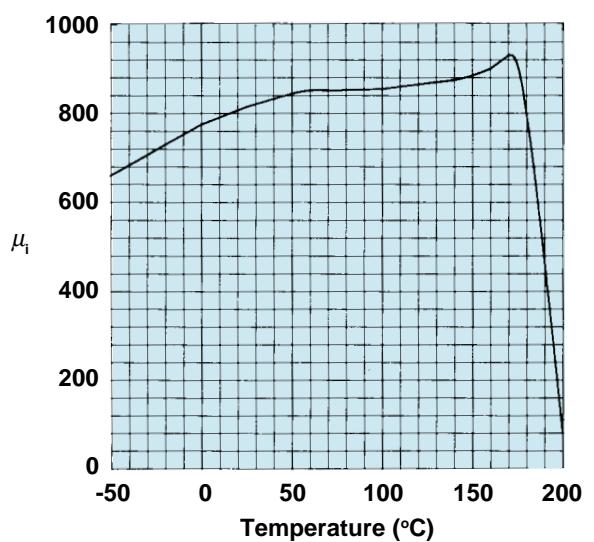
Measured on a 25.4mm OD toroid using HP 4275A.

Hysteresis Loop



Measured on a 25.4mm OD toroid.

Initial Permeability vs. Temperature



Measured on a 25.4mm OD toroid at 100 kHz using a HP 4275A.

43 Material

Primary Characteristics

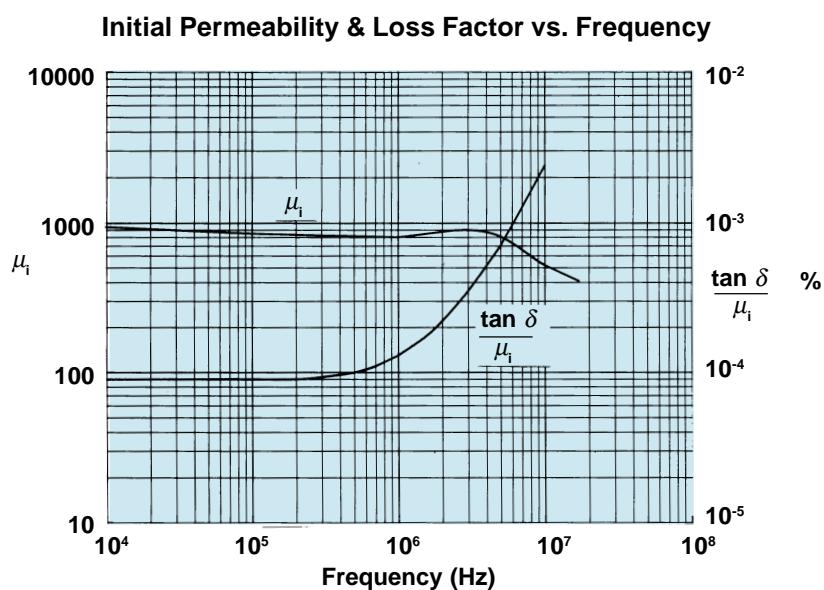
High impedance
High resistivity

Applications

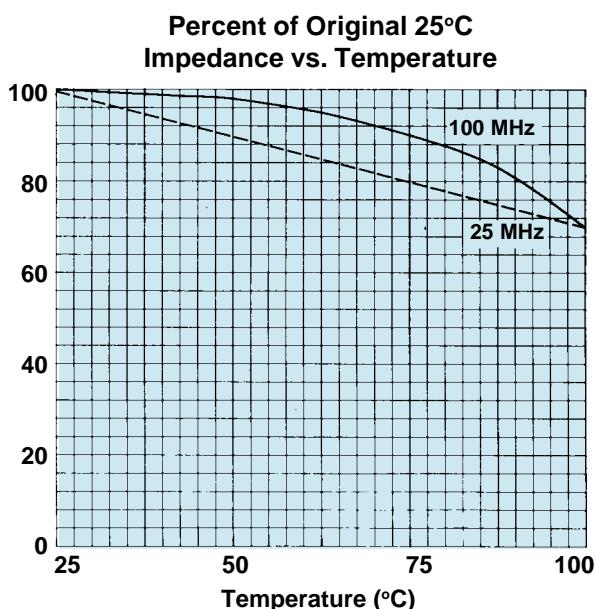
Recommended suppression material of unwanted signals between 30 MHz and 200 MHz.

Available Core Shapes

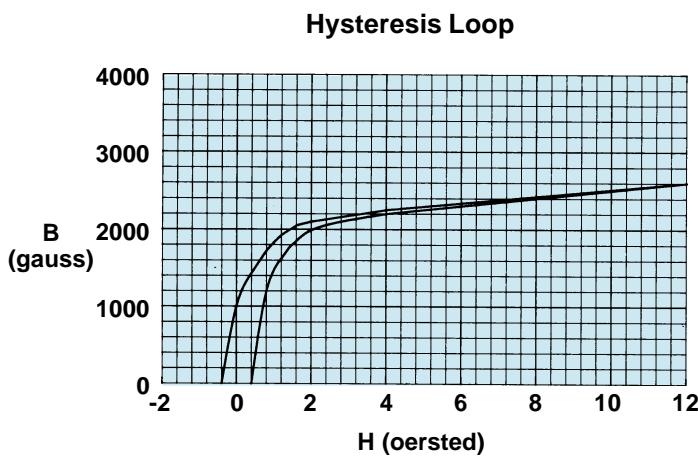
Shield beads, SM beads, beads on leads, wound beads, PC beads, flat and round cable suppression cores, bobbins, toroids, multi-aperture cores



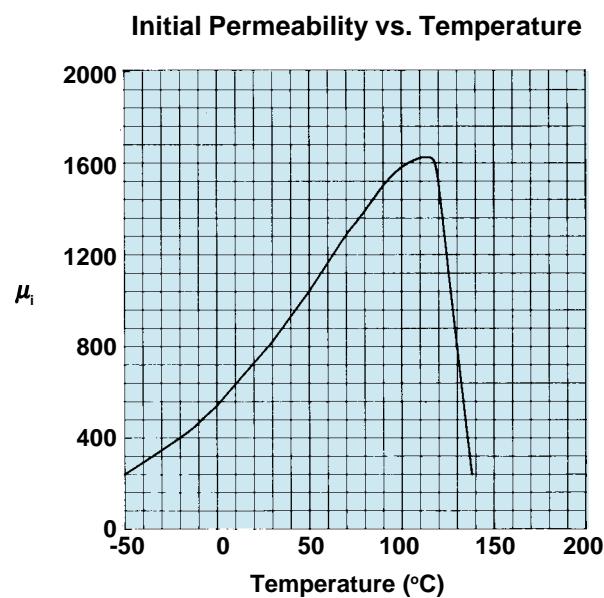
Measured on a 25.4mm OD toroid using HP 4275A and HP 4191A.



Measured on a 25.4mm OD toroid using a HP 4191A.



Measured on a 25.4mm OD toroid.



Measured on a 25.4mm OD toroid at 100 kHz using a HP 4275A.

73 Material

Primary Characteristics

High impedance
Temperature stable impedance
High initial permeability

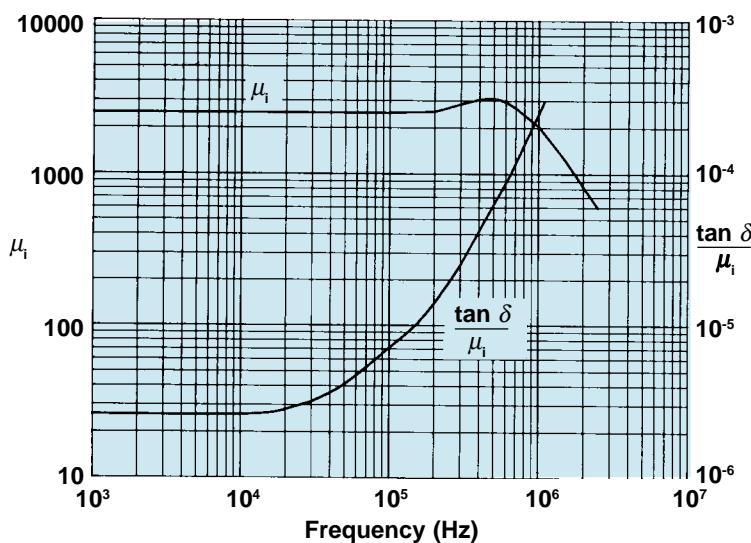
Applications

Optimum material for EMI suppression below 30 MHz
Broadband transformers

Available Core Shapes

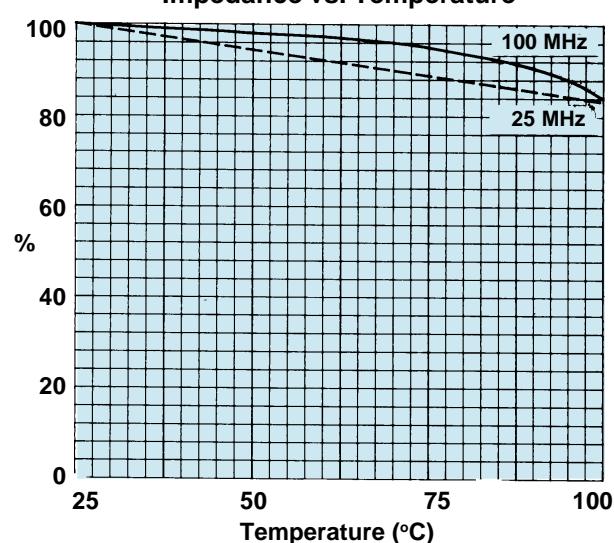
Shield beads, beads on leads,
multi-aperture cores, SM beads

Initial Permeability & Loss Factor vs. Frequency



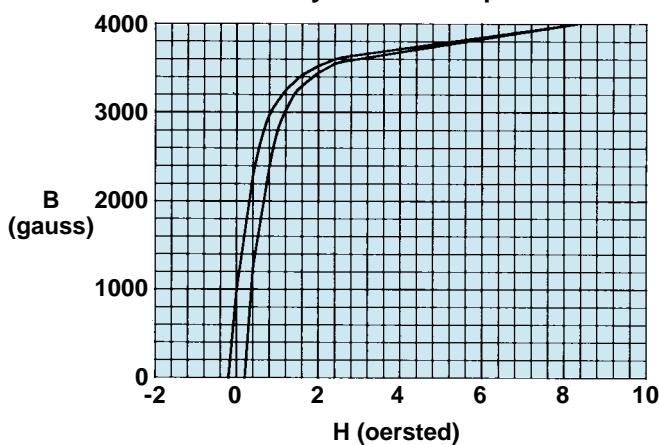
Measured on a 25.4mm OD toroid using HP 4275A.

Percent of Original 25°C Impedance vs. Temperature



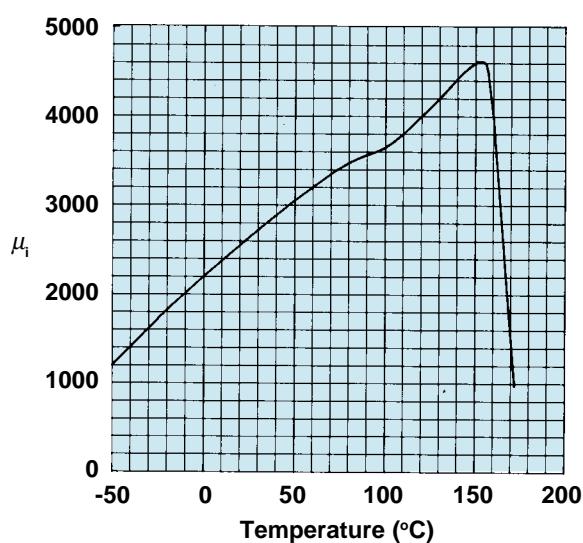
Measured on a 25.4mm OD toroid using a HP 4191A.

Hysteresis Loop



Measured on a 25.4mm OD toroid.

Initial Permeability vs. Temperature

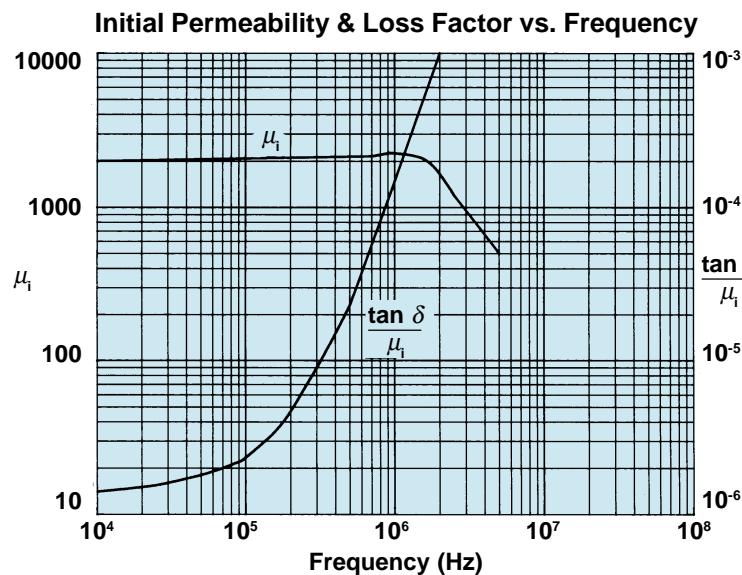


Measured on a 25.4mm OD toroid at 100 kHz using a HP 4275A.

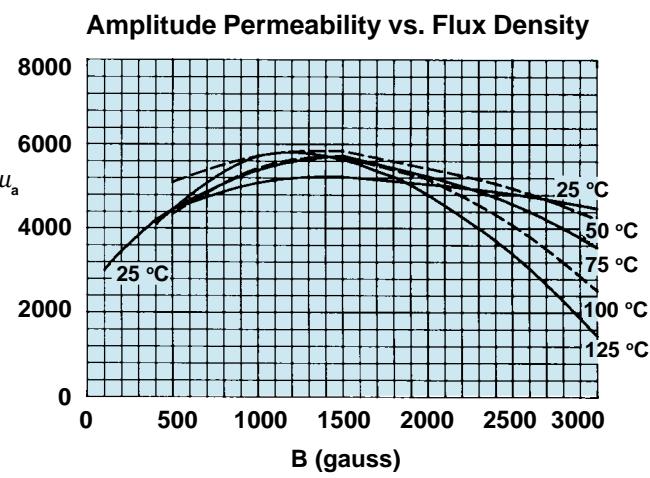
77 Material

Primary Characteristics

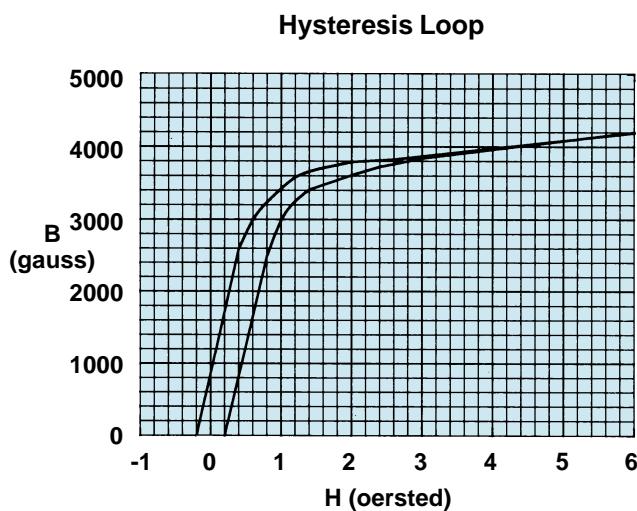
- High flux density at high temperatures.
- Low core loss at high flux densities and high temperatures.
- High amplitude permeabilities at high temperatures.
- High Curie temperature.



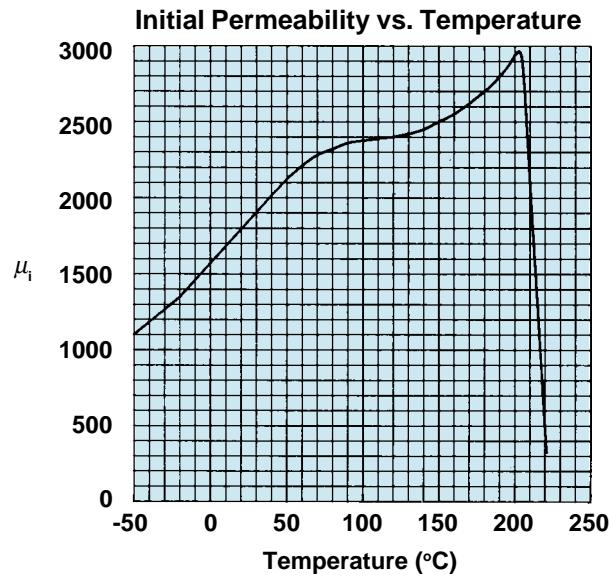
Measured on a **25.4mm** OD toroid using a HP 4275A.



Measured on a **25.4mm** OD toroid at 10 kHz.



Measured on a **25.4mm** OD toroid.



Measured on a **25.4mm** OD toroid at 100 kHz using a HP 4275A.

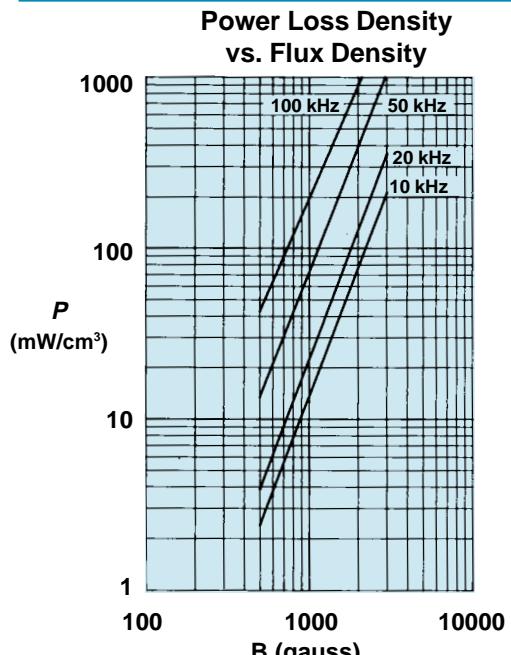
77 Material

Applications

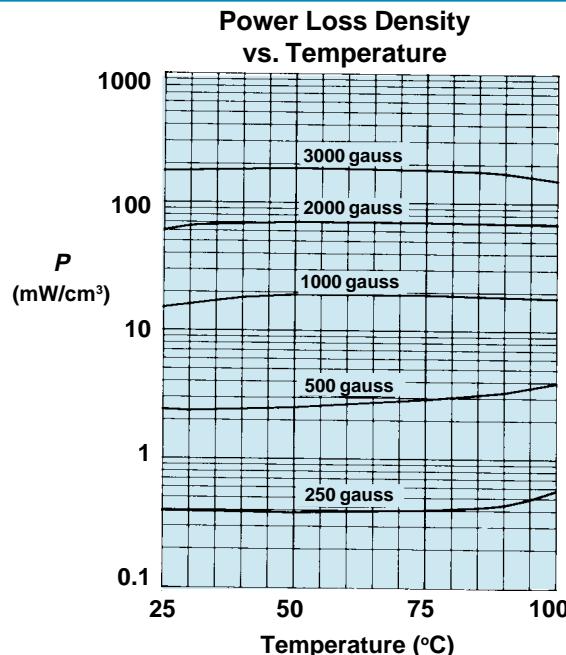
Transformers and inductors for switched-mode power supplies and DC-DC converters.
 Power filters
 Ignition coils
 Broadband transformers

Available Core Shapes

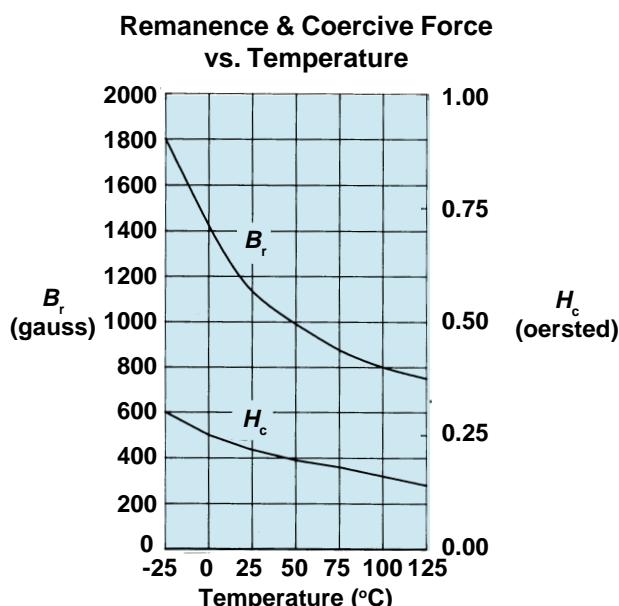
Pot cores, EP cores, PQ cores, ETD cores, E & I cores, U cores, discs, slugs, toroids, bobbins



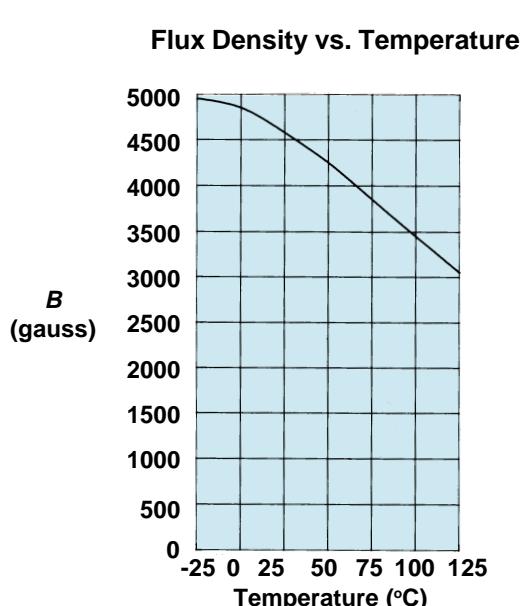
Measured on a 25.4mm OD toroid using a Clarke Hess 255 VAW at 100°C.



Measured on a 25.4mm OD toroid at 10 kHz using a Clarke Hess 255 VAW.



Measured on a 25.4mm OD toroid.
 $H = 10$ oersted.



Measured on a 25.4mm OD toroid.
 $H = 10$ oersted.

78 Material

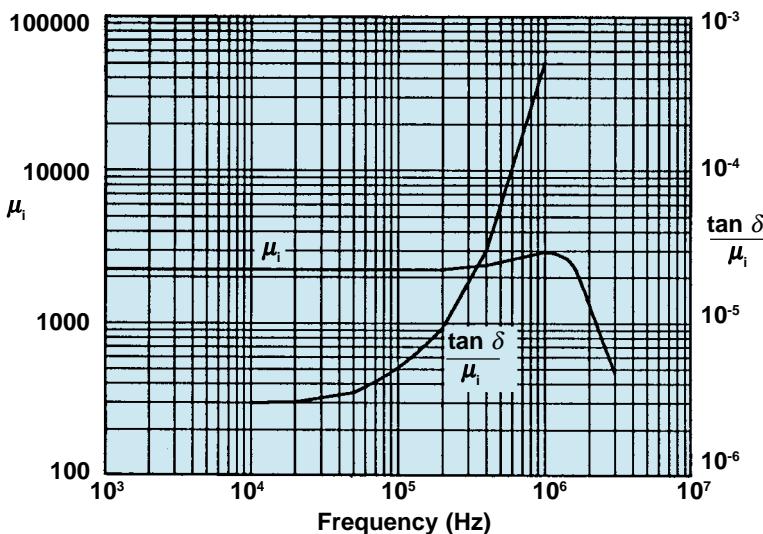
Primary Characteristics

Low core loss at high temperatures and flux densities for frequencies up to 200 kHz.

High amplitude permeability at high temperatures and excitation levels.

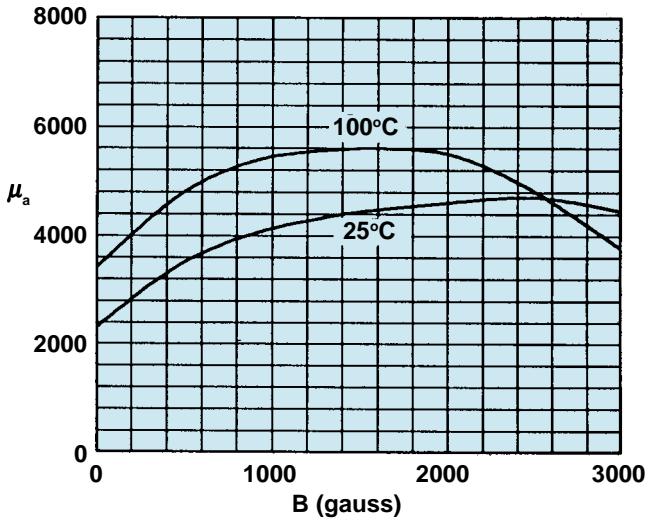
Curie temperature >200°C.

Initial Permeability & Loss Factor vs. Frequency



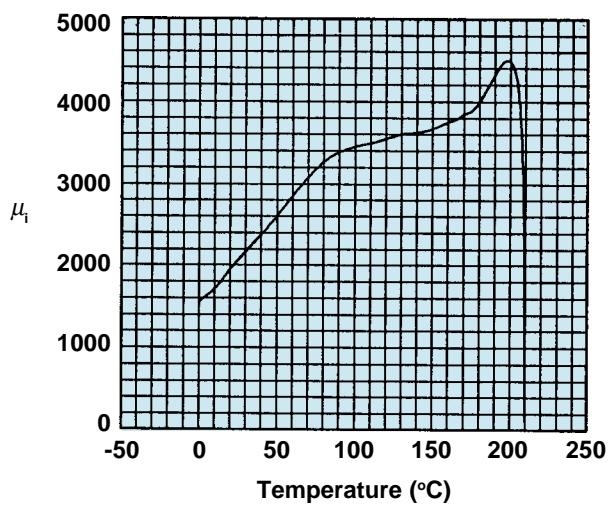
Measured on a 25.4mm OD toroid using a HP 4275A.

Amplitude Permeability vs. Flux Density



Measured on a 25.4mm OD toroid at 10 kHz.

Initial Permeability vs. Temperature



Measured on a 25.4mm OD toroid at 100 kHz using a HP 4275A.

Fair-Rite Products Corp.

Phone: (888) FAIR RITE / (914) 895-2055 • FAX: (888) FERRITE / (914) 895-2629 • www.fair-rite.com • E-Mail: [\(888\) 324-7748](mailto:ferrites@fair-rite.com)

One Commercial Row, Wallkill, NY 12589-0288

(888) 337-7483

78 Material

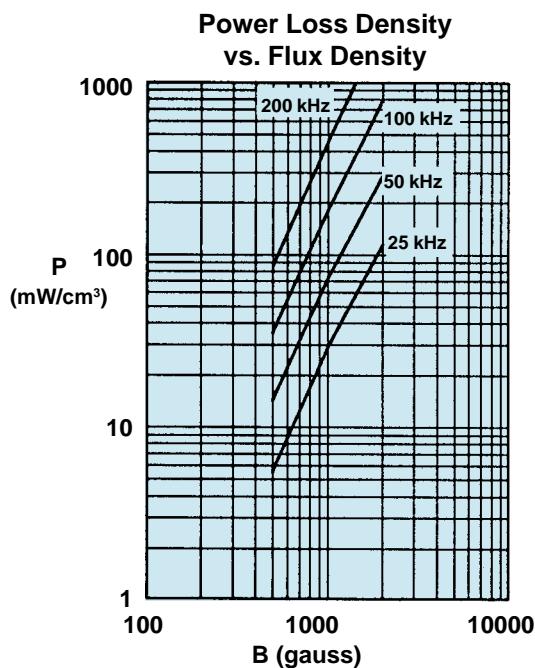
Applications

Transformers and inductors for high frequency switched-mode power supplies and DC converters.

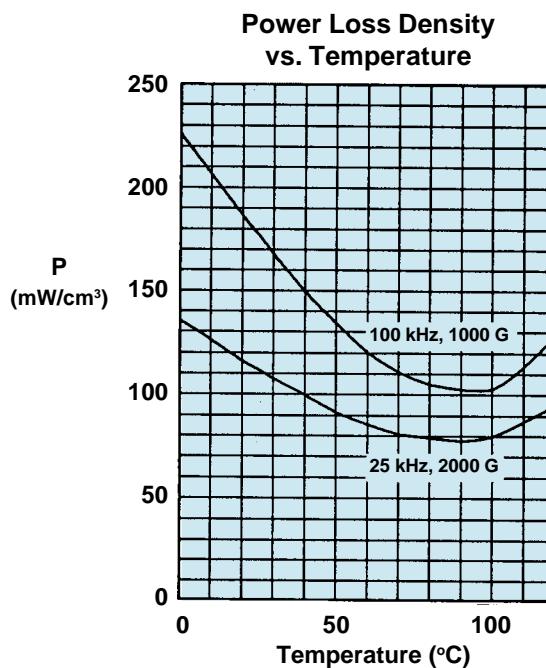
High frequency electronic ballasts for fluorescent lighting.

Available Core Shapes

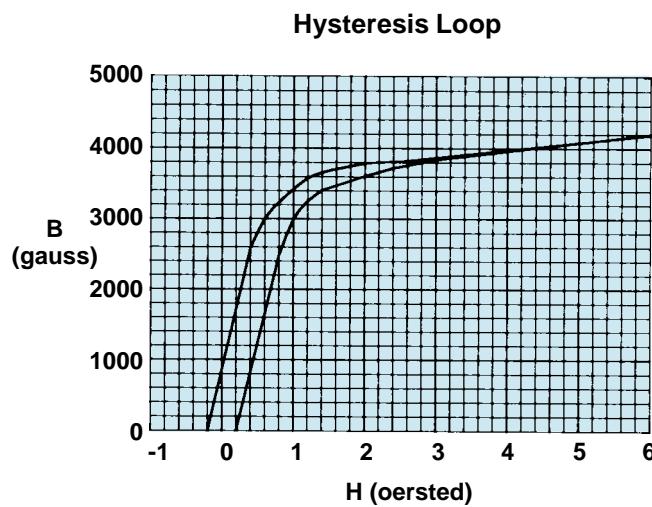
Pot cores, EP cores, PQ cores, E & I cores, ETD cores



Measured on a 25.4mm OD toroid using a Clarke Hess 258 VAW at 25° C.



Measured on a 25.4mm OD toroid using a Clarke Hess 258 VAW.



Measured on a 25.4mm OD toroid.

75 Material

Primary Characteristics

High initial permeability
Low core loss

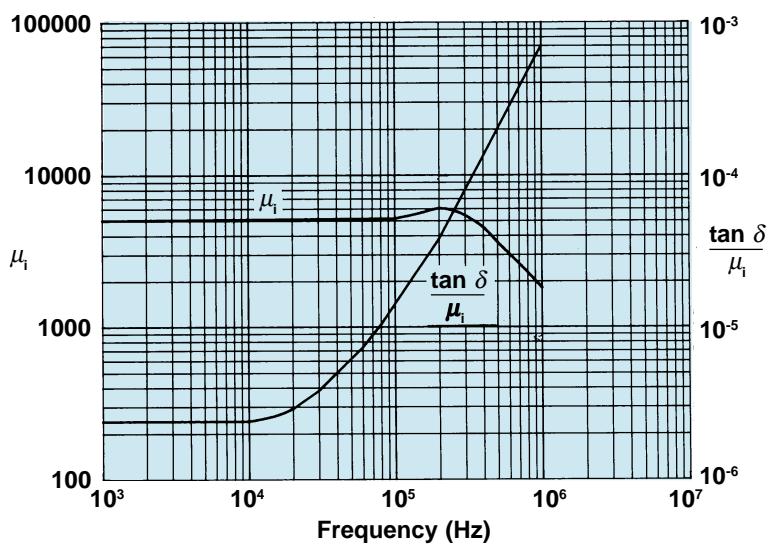
Applications

Pulse and broadband transformers
Common-mode power chokes
Ground-fault interrupters

Available Core Shapes

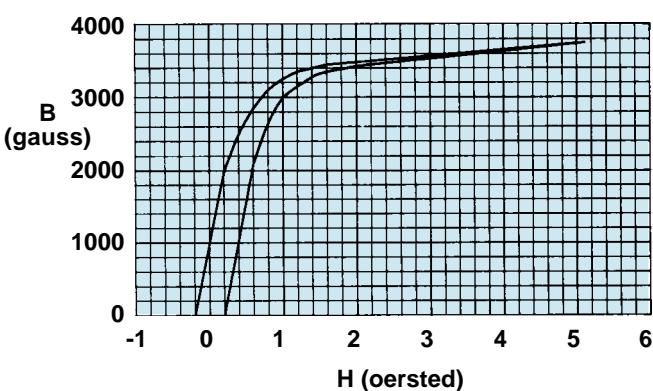
Toroids, E & I cores, EP cores

Initial Permeability & Loss Factor vs. Frequency



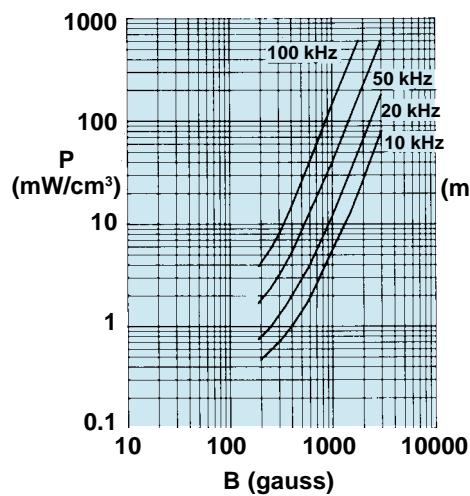
Measured on a 25.4mm OD toroid using a HP 4275A.

Hysteresis Loop



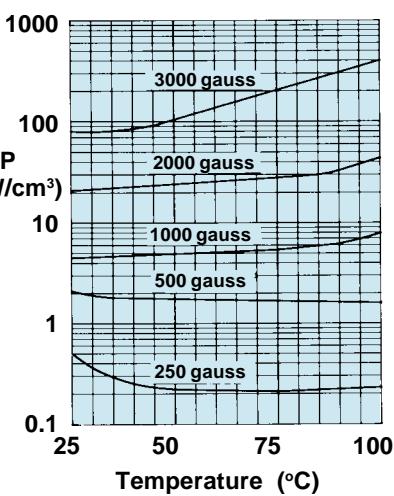
Measured on a 25.4mm OD toroid.

Power Loss Density vs. Flux Density



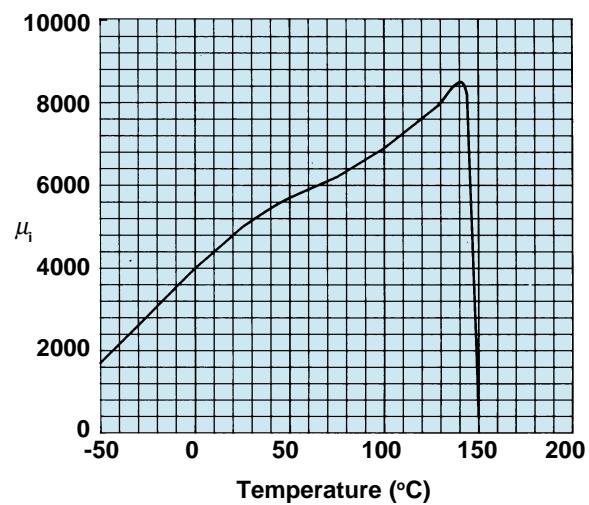
Measured on a 25.4mm OD toroid using a Clarke Hess 255 VAW.

Power Loss Density vs. Temperature



Measured on a 25.4mm OD toroid at 10 kHz using a Clarke Hess 255 VAW.

Initial Permeability vs. Temperature



Measured on a 25.4mm OD toroid at 100 kHz using a HP 4275A.

76 Material

Primary Characteristics

Very high initial permeability
Low core loss
Acceptable Curie temperature

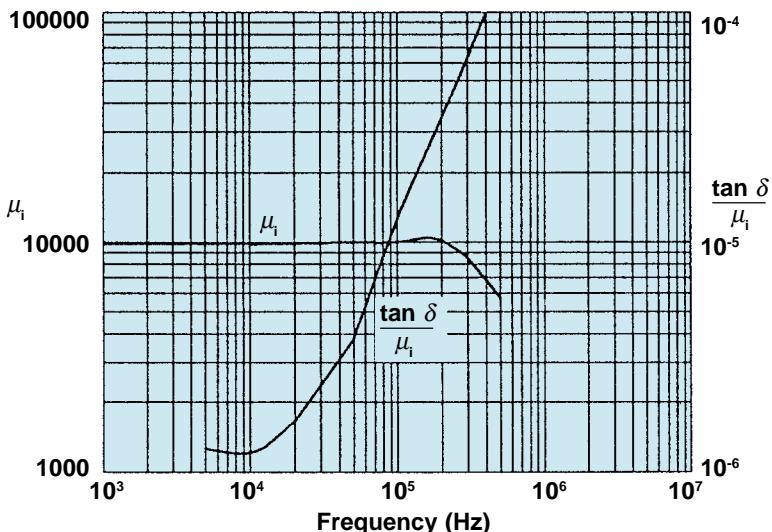
Applications

Pulse and broadband transformers
Ground-fault interrupters
LAN Transformers

Available Core Shapes

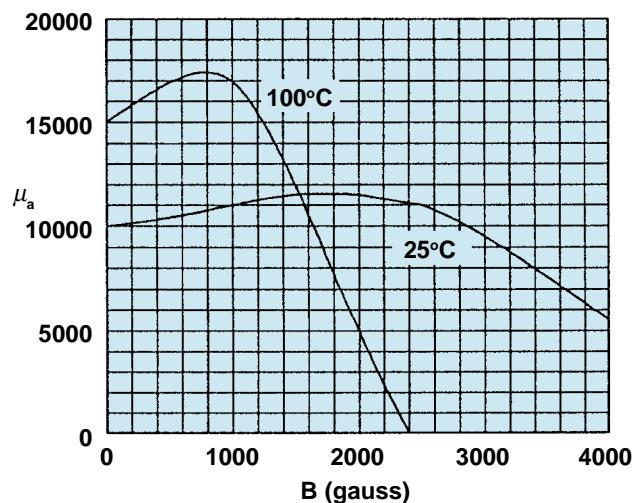
Toroids

Initial Permeability & Loss Factor vs. Frequency



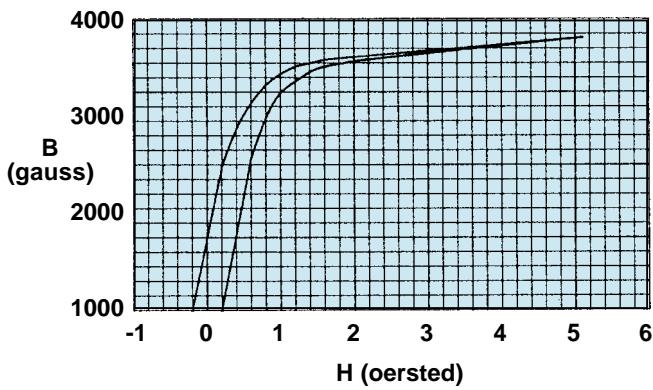
Measured on a 25.4mm OD toroid using a HP 4275A.

Amplitude Permeability vs. Flux Density



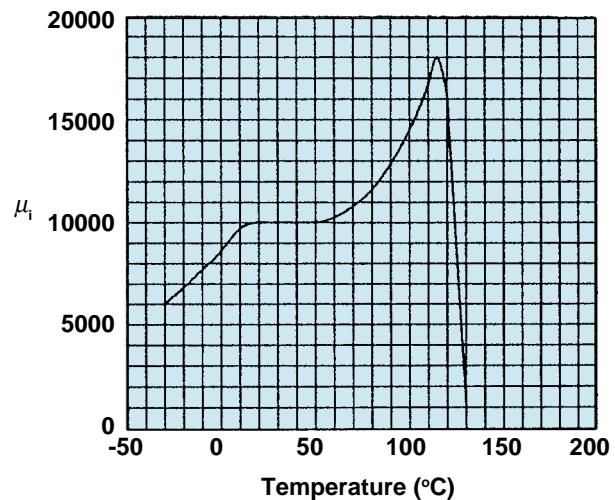
Measured on a 25.4mm OD toroid at 10 kHz.

Hysteresis Loop



Measured on a 25.4mm OD toroid.

Initial Permeability vs. Temperature



Measured on a 25.4mm OD toroid at 10 kHz using a HP 4275A.

Glossary of Terms

Air Core Inductance - L_o (H)

The inductance that would be measured if the core had unity permeability and the flux distribution remained unaltered.

Coercive Force - H_c (oersted)

The magnetizing field strength required to bring the magnetic flux density of the magnetized material to zero.

Core Constant - C_1 (cm⁻¹)

The summation of the magnetic path lengths of each section of a magnetic circuit divided by the corresponding magnetic area of the same section.

Core Constant - C_2 (cm⁻³)

The summation of the magnetic path lengths of each section of a magnetic circuit divided by the square of the corresponding magnetic area of the same section.

Curie Temperature - T_c (°C)

The transition temperature above which a ferrite loses its ferromagnetic properties.

Disaccommodation - D

The proportional decrease of permeability after a disturbance of magnetic material, measured at constant temperature, over a given time interval.

Disaccommodation Factor - DF

The disaccommodation factor if the disaccommodation after magnetic conditioning divided by the permeability of the first measurement times \log_{10} of the ratio of time intervals.

Effective Dimensions of a Magnetic Circuit -

Area A_e (cm²), Path Length l_e (cm) and Volume V_e (cm³)

For a magnetic core of given geometry, the magnetic path length, the cross-sectional area and the volume that a hypothetical toroidal core of the same material properties should possess to be the magnetic equivalent to the given core.

Field Strength - H (oersted)

The parameter characterizing the amplitude of the alternating field strength.

Flux Density - B (gauss)

The corresponding parameter for the induced magnetic field in an area perpendicular to the flux path.

Flux Density, saturation - B_s (gauss)

The maximum intrinsic induction possible in a material.

Inductance Factor - A_L (nH)

Inductance of a coil on a specified core divided by the square of the number of turns. (Unless otherwise specified the inductance test conditions for the inductance factor are at flux density <10 gauss).

Loss Factor - $\tan \delta/\mu_i$

The phase of displacement between the fundamental components of the flux density and the field strength divided by the initial permeability.

Magnetic Constant - μ_o

The permeability of free space.

Magnetic Hysteresis

In the magnetic material, the irreversible variation of the flux density or the magnetization which is associated with the change of magnetic field strength and is independent of the rate change.

Magnetically Soft Material

A magnetic material with low coercivity.

Permeability, amplitude - μ_a

The quotient of the peak value of the flux density and the peak value of the applied field strength at a stated amplitude of either, with no static present.

Permeability, effective - μ_e

For a magnetic circuit constructed with an air gap or air gaps, the permeability of a hypothetical homogeneous material which would provide the same reluctance.

Permeability, incremental - μ_Δ

Under stated conditions the permeability obtained from the ratio of the flux density and the applied field strength of an alternating field and a superimposed static field.

Permeability, initial - μ_i

The permeability obtained from the ratio of the flux density, kept at <10 gauss, and the required applied field strength. Material initially in a specified neutralized state.

Power Loss Density - P (mW/cm³)

The power absorbed by a body of ferrimagnetic material and dissipated as heat, when the body is subject to an alternating field which results in a measurable temperature rise. The total loss is divided by the volume of the body.

Remanence - B_r (gauss)

The flux density remaining in a magnetic material when the applied magnetic field strength is reduced to zero.

Temperature Coefficient - TC

The relative change of the quantity considered, divided by the difference in the temperatures producing it.

Temperature Factor - TF

The fractional change in the initial permeability over temperature range, divided by the initial permeability.

Magnetic Design Formulas

Effective Core Parameters

$$\begin{aligned} C_1 &= \Sigma l/A \quad (\text{cm}^{-1}) & C_2 &= \Sigma l/A^2 \quad (\text{cm}^{-3}) \\ l_e &= C_1^2/C_2 \quad (\text{cm}), & A_e &= C_1/C_2 \quad (\text{cm}^2) \text{ and} & V_e &= C_1^3/C_2^2 \quad (\text{cm}^3) \end{aligned}$$

Flux Density Peak

$$\hat{B} = \frac{E 10^8}{4.44 f N A_e} * \quad (\text{gauss})$$

Field Strength (Peak)

$$\hat{H} = \frac{.4 \pi N I_p}{l_e} \quad (\text{oersted})$$

Where E = RMS sine wave voltage (V)
 f = Frequency (Hz)
 A_e = Effective cross-sectional area (cm^2)
 l_e = Effective path length (cm)
 I_p = Peak current (A)
 N = Number of turns

* To check for maximum peak flux density in a non-uniform core set substitute A_{\min} for A_e .

Air Core Inductance

$$L_o = \frac{4 \pi N^2 10^{-9}}{C_1} \quad (\text{H})$$

C_1 in cm^{-1}

Number of Turns

$$N = \sqrt{\frac{L 10^9}{A_L}} \quad L \text{ in H}$$

Inductance

$$\begin{aligned} L &= N^2 A_L \quad (\text{nH}) \\ L &= \mu_i \frac{4 \pi N^2}{C_1} 10^{-9} \quad (\text{H}) \\ L &= \mu_e \frac{4 \pi N^2}{C_1} 10^{-9} \quad (\text{H}) \end{aligned}$$

$\left. \right\} C_1 \text{ in cm}^{-1}$

Effective Permeability

$$\mu_e = \frac{l_e}{l_e/\mu_i + l}$$

Where l_e = Effective path length
 l = Air gap length

Attenuation

$$20 \log_{10} \frac{|Z_s + Z_L + Z_{sc}|}{|Z_s + Z_L|} \quad (\text{dB})$$

Number of Turns

$$Q = \frac{2 \pi f L_s}{R_s} = \frac{R_p}{2 \pi f L_p}$$

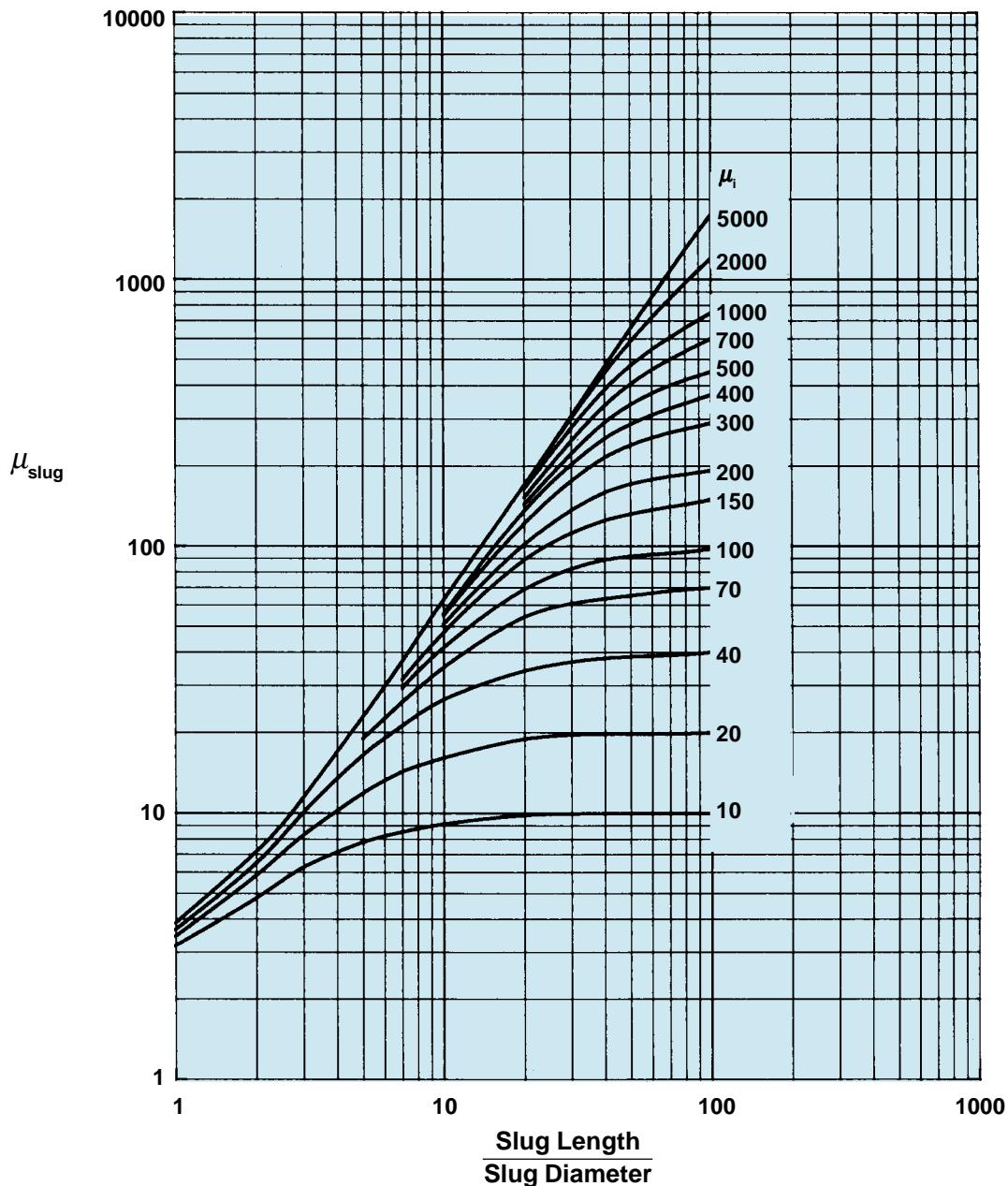
Where Z_s = Source impedance
 Z_L = Load impedance
 Z_{sc} = Suppression core impedance

Effective Permeability of Ferrite Slugs

This family of curves shows the value of the effective permeability of a ferrite slug as a function of its length to diameter ratio, as well as a function of the material permeability of the slug. It illustrates that generally, a great difference exists between the material permeability and the

effective permeability of a slug. It also illustrates how, in some instances, the effective permeability of a slug can be influenced by changing its mechanical dimensions more than by changing its material permeability, while in other cases, the reverse is true.

Slug Permeability vs. Slug Length divided by Slug Diameter



Wire Table of Copper Magnet Wire

AWG & B&S Gauge	Diameter (Inch)	Cross-Sectional Area		Feet per Ohm (20°C)	Ohms per 1000 ft (20°C)	Amperes for 1mA/cir mil	Turns per Inch ²
		(Inch ²)	(cir mils)				
10	.1019	.00815	10380	1001	1.00	10.4	92
11	.0907	.00647	8234	794	1.26	8.25	118
12	.0808	.00513	6530	630	1.59	6.54	146
13	.0719	.00407	5178	499	2.00	5.18	180
14	.0641	.00322	4107	396	2.53	4.11	231
15	.0571	.00256	3257	314	3.18	3.26	275
16	.0508	.00203	2583	249	4.02	2.59	346
17	.0453	.00161	2048	198	5.06	2.05	432
18	.0403	.00127	1624	157	6.39	1.62	544
19	.0359	.00101	1288	124	8.05	1.29	679
20	.0320	.000804	1022	98.5	10.2	1.03	854
21	.0285	.000638	810.1	78.1	12.8	.81	1065
22	.0254	.000505	642.4	62.0	16.1	.64	1345
23	.0226	.000400	509.5	49.1	20.4	.51	1675
24	.0201	.000317	404.0	39.0	25.7	.40	2095
25	.0179	.000252	320.4	30.9	32.4	.321	2630
26	.0159	.000200	254.1	24.5	40.8	.255	3325
27	.0142	.000158	201.5	19.4	51.4	.201	4110
28	.0126	.000126	159.8	15.4	64.9	.160	5210
29	.0113	.000100	126.7	12.2	81.9	.128	6385
30	.0100	.0000785	100.5	9.7	103.1	.100	8145
31	.0089	.0000622	79.7	7.7	130.1	.079	10,097
32	.0080	.0000503	63.2	6.1	163	.064	12,270
33	.0071	.0000396	50.1	4.8	206	.050	15,615
34	.0063	.0000312	39.8	3.83	261	.040	19,655
35	.0056	.0000248	31.5	3.04	330	.0316	25,530
36	.0050	.0000196	25.0	2.41	415	.0250	31,405
37	.0045	.0000159	19.8	1.91	524	.0203	39,570
38	.0040	.0000126	15.7	1.52	670	.0160	49,070
39	.0035	.00000962	12.5	1.20	832	.0122	65,790
40	.0031	.00000755	9.89	0.953	1049	.0098	82,180
41	.0028	.00000616	7.84	0.756	1323	.0079	98,860
42	.0025	.00000491	6.20	0.598	1672	.0062	121,175
43	.0022	.00000380	4.93	0.476	2101	.0048	158,245
44	.0020	.00000314	3.88	0.374	2674	.0039	205,515
45	.0018	.00000254	3.10	0.299	3344	.0032	249,855
46	.0016	.00000201	2.46	0.238	4202	.0025	310,205

Technical Information

The Effect of Direct Current on the Inductance of a Ferrite Core

Introduction

If ferrite cores are used in the design of transformers, chokes or filters, which are required to carry direct current, it is necessary to predict the degree of inductance degradation caused by the static field. When dc flows through the winding of a ferromagnetic device, it tends to pre-magnetize the core and reduce its inductance. The permeability of a ferrite material measured with superimposed dc might increase slightly for very low values of dc ampere-turns, but then it progressively decreases as the dc field is increased and the core approaches saturation. This permeability is referred to as the incremental permeability μ_{Δ} . If an air gap is introduced into the magnetic path of a core, the reluctance is increased hence the inductance is decreased. However, the core's capacity for dc ampere-turns without a degradation in inductance is significantly improved, albeit at the expense of a lower effective permeability.

DC Bias in Gapped Cores

The use of graphs such as the Hanna* curves has simplified the tedious trial and error methods often employed when designing inductors with superimposed dc. A Hanna curve is created by measuring the inductance vs. dc bias of various core sizes and gap lengths of the same material grade. The measured data is used to create curves such as those plotted in Figure 1 (this curve is specific for a set of 9477015002 E cores). A line is drawn connecting the individual curves through the point of tangency. The graphs are then normalized by dividing the vertical scale of Figure 1 by the effective core volume V_e and the horizontal scale and the gap lengths by the effective path length l_e of the core set. The individual curves, once normalized, overlay creating the Hanna curve. Figure 2 is such a curve for Fair-Rite 77 material and can be used for all core sets in that material.

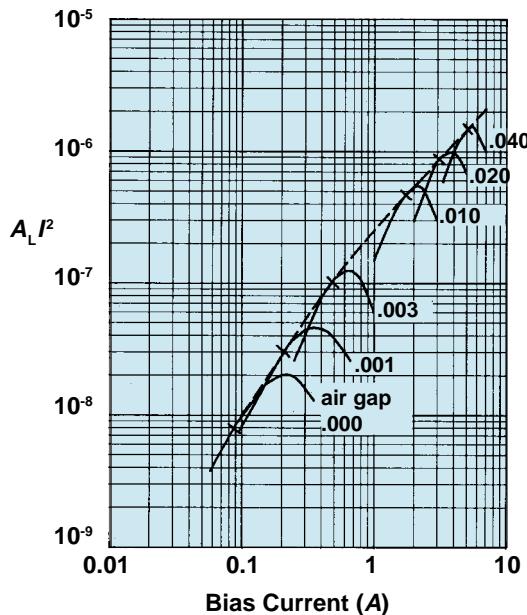


Figure 1 Product Inductance Factor and Current Squared vs. DC Current for a pair of 9477015002 E Cores.

Design Example

For a typical output choke application, the designer knows a number of design criteria such as the required inductance, the direct current, alternating ripple current and allowable dc resistance. He will also have requirements for core size, ambient temperature and often a preference for a particular core geometry.

*Footnote: C.R. Hanna presented a paper "Design of Reactances and Transformers which Carry Direct Current" at the 1927 Winter Convention of AIEE. The paper provided a method of calculating the air gap that will yield the maximum inductance for a given number of turns, with a specified amount of dc, for a particular material.

Technical Information

The following example illustrates the use of the Hanna curve in the design of an inductor.

Inductor specifications:

Minimum inductance	$L = 1 \text{ mH}$
Direct current	$I_{dc} = 1 \text{ A}$
Alternating ripple current	$I_{ac} = 0.2 \text{ A}$
Maximum dc resistance	$R_{dc} < 0.2 \Omega$

Step 1. Initial Core Selection.

Using the Hanna curve for 77 material of Figure 2, select a value for LP/V_e approximately mid range on the vertical axis, that is between 10^{-4} and 10^{-3} . Any value greater than 10^{-3} will work the ferrite too hard and the dc resistance is apt to be high. Anything lower than 10^{-4} will result in a conservative design and the dc resistance will be quite low.

Select therefore $LP/V_e = 3.5 \cdot 10^{-4}$

Calculate V_e from:

$$\begin{aligned} V_e &= LP/3.5 \cdot 10^{-4} \\ L_{\min} &= 1 \text{ mH, design for } L = 1.1 \cdot 10^{-3} \text{ H} \\ I_e &= I_{dc} + I_{ac}/2 = 1 + 0.2/2 = 1.1 \text{ A} \\ V_e &= 1.1 \cdot 10^{-3} \times 1.1^2/3.5 \cdot 10^{-4} = 3.8 \text{ cm}^3 \end{aligned}$$

Select E core (preferred core shape), based upon the calculated core volume of 3.8 cm^3 from the catalog, pages 106 and 107. Two Fair-Rite E cores are considered:

$$\begin{aligned} 9477015002 & V_e = 1.95 \text{ cm}^3 \text{ and} \\ 9477014002 & V_e = 3.92 \text{ cm}^3. \end{aligned}$$

The 9477014002 is closest and will be used in this inductor design. The core parameters for this E core set are:

$$I_e = 4.9 \text{ cm}, A_e = .80 \text{ cm}^2 \text{ and } V_e = 3.92 \text{ cm}^3.$$

Recalculate

$$LP/V_e = 1.1 \cdot 10^{-3} \times 1.1^2/3.92 = 3.4 \cdot 10^{-4}.$$

Step 2. Number of Turns, Wire Size and Wire Fit.

From Figure 2, a $LP/V_e = 3.4 \cdot 10^{-4}$ yields a H value of 17 oersted.

Calculate turns N from the formula $H = .4 \pi NI/I_e$ oersted.

$$N = 17 \times 4.9/.4 \times \pi \times 1.1 = 60.3 \text{ or } 61 \text{ turns.}$$

From the core dimensions, the core winding area can be calculated, see Table 1.

Winding area for a set of E cores 9477014002 is:

$$\begin{aligned} A_w &= D (\text{F-E}) \text{ in inch}^2. \\ A_w &= .255 (.740-.250) = .125 \text{ inch}^2. \end{aligned}$$

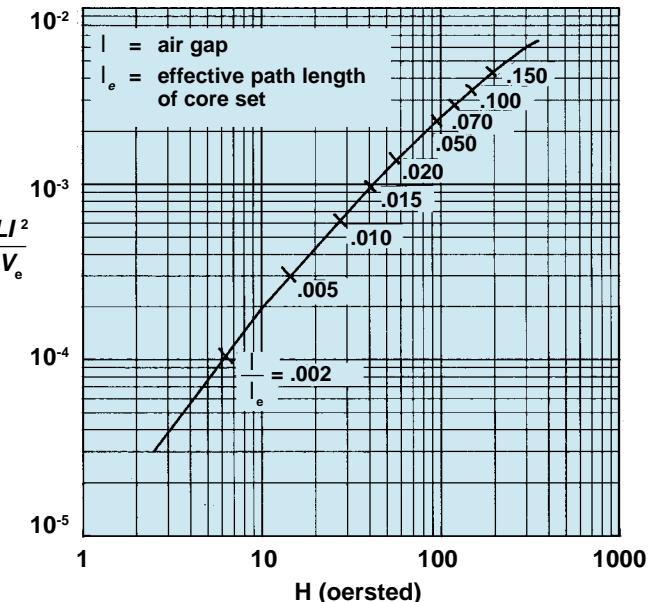


Figure 2 Hanna Curve for Core Sets in Fair-Rite 77 material.

Table 1
Core Winding Area (inch²)

E Cores	D(F-E)
ETD Cores	D(F-E)
PQ Cores	D(F-E)
Pot Cores	F(B-C)
EP Cores	F(B-C)

Since the winding area of the appropriate bobbin is smaller than the core winding area, a correction factor F_c has to be used to determine the bobbin winding area. Figure 3 gives this correction-factor F_c as a function of the calculated core winding area A_w . A set of E cores 9477014002 has a $A_w = .125 \text{ inch}^2$, from Figure 3 can be determined that the $F_c = .55$, therefore the bobbin winding area is $.55 \times .125 = .069 \text{ inch}^2$. Using a conservative current density of 1 mA per circular mil or 1275 A per inch², an initial wire size selection of 20 AWG can be made from the Wire Table on page 25. To determine the dc resistance of the winding, first find the average length of turn from Table 2.

Table 2
Mean Length of Turn (inch)

E Cores	$2 (\text{C+F})$
ETD Cores	$.5 \pi (\text{E+F})$
PQ Cores	$.5 \pi (\text{E+F})$
Pot Cores	$.5 \pi (\text{B+C})$
EP Cores	$.5 \pi (\text{B+C})$

Technical Information

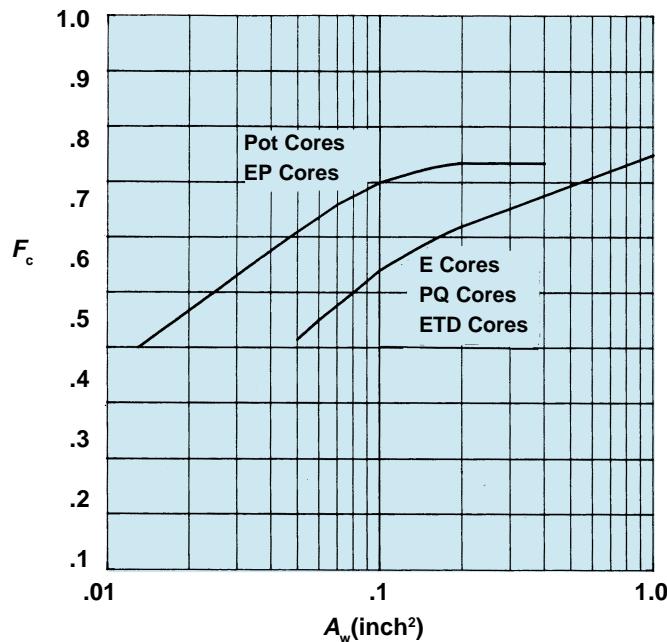


Figure 3 Correction Factor F_c vs. Core Winding Area A_w .

Average length of turn for E 9477014002 is:

$$l_{avg.} = 2(C+F)$$

$$l_{avg.} = 2(.500 + .740) = 2.48 \text{ inch.}$$

$$R_{dc} = 2.48 \times 61 \times 10.2 / 12000 = 0.13 \Omega$$

(From the Wire Table, 1000 ft of 20 AWG has a resistance of 10.2 Ω)

To check for winding fit, multiply the number of turns per square inch for 20 AWG from the Wire Table with the bobbin winding area of .069 inch². For 20 AWG, the bobbin winding area can accommodate $854 \times .069 = 58.9$ turns. This is too close to the calculated turns for an easily manufactured magnetic design. Use 21 AWG wire instead.

$$R_{dc} = 2.48 \times 61 \times 12.8 / 12000 = 0.16 \Omega.$$

Winding fit for 21 AWG:

$$N = 1065 \times .069 = 73.5, \text{ well above the required 61 turns.}$$

Step 3. Air gap.

Going back to Figure 2, for $L/P/V_e = 3.4 \times 10^{-4}$ and a $H = 17$ oersted, a l/l_e ratio of approximately .006 is found.

$$\text{The gap length} = .006 \times l_e.$$

$$l = .006 \times 4.9 / 2.54 = .012 \text{ inch.}$$

To summarize:

E core 9477014002

Wire size 21 AWG

$N = 61$ turns

Gap length .012 inch

The graphs in Figures 4 through 8 show the inductance factors or A_L values as a function of the air gaps for the different core types and sizes. The air gap determined in the design example and the air gaps shown in Figures 4 through 8 represent the total air gap. The most practical way to obtain this air gap is to grind this gap into the center leg of one of the core halves. Non-metallic shims can also be used to obtain the desired air gap. This is usually done by placing shims between the outer legs or outside rims of the core halves. In cores with a uniform cross-sectional area, the A_L value or inductance index will be the same whether the core is gapped or shims are used that have a thickness half the total air gap. For cores that have a non-uniform cross-sectional area the shim thickness can be calculated from:

$$\text{Shim thickness} = \frac{\text{center mating area}}{\text{total mating area}}$$

The above example of the E core 9477014002, a core with a uniform cross-sectional area, can therefore use .006 inch shims between the outer legs.

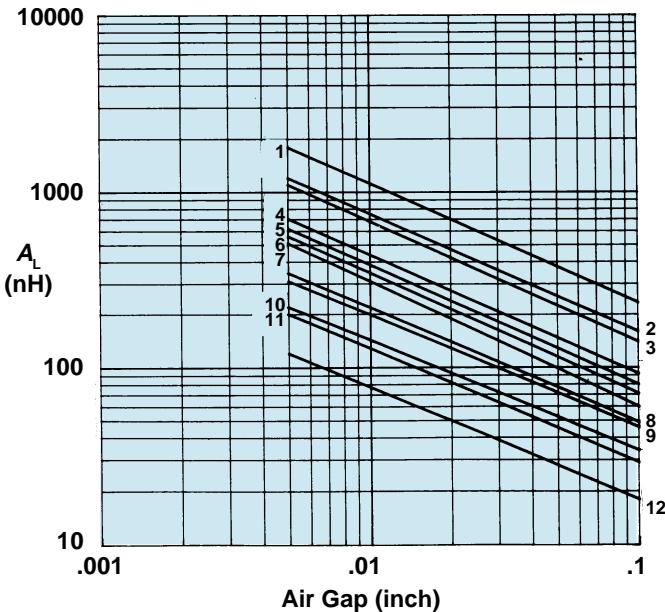


Figure 4 A_L vs. Gap for E Cores in 77 and 78 material.

1 94 -- 625002	5 94 -- 375002	9 94 -- 015002
2 94 -- 500002	6 94 -- 014002	10 94 -- 016002
3 94 -- 036002	7 94 -- 018002	11 94 -- 020002
4 94 -- 017002	8 94 -- 012002	12 94 -- 019002

Technical Information

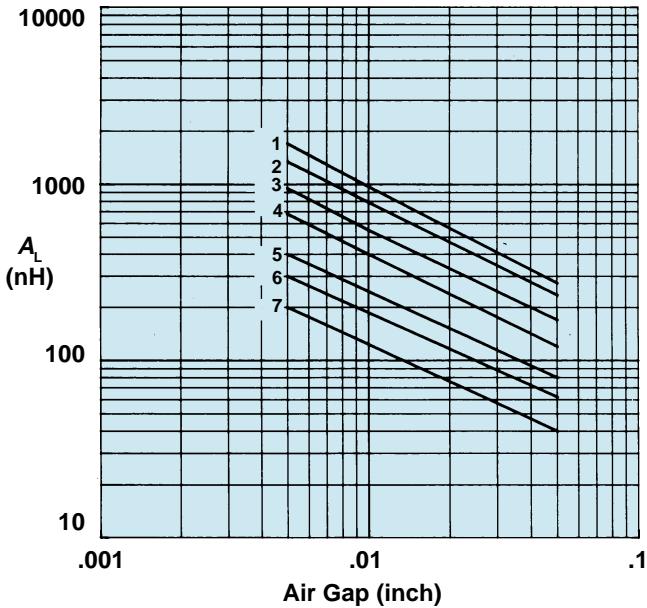


Figure 5 A_L vs. Gap for Pot Cores in 77 and 78 material.

1 56 -- 422921	4 56 -- 261621	6 56 -- 181121
2 56 -- 362221	5 56 -- 221321	7 56 -- 140821
3 56 -- 301921		

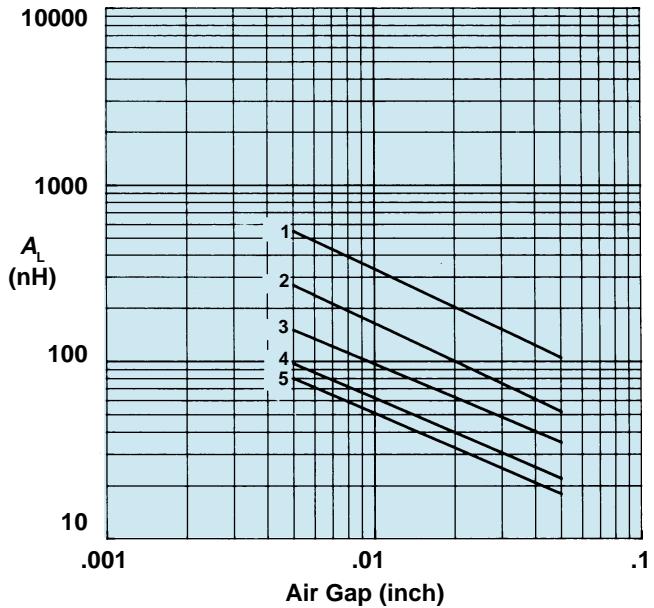


Figure 6 A_L vs. Gap for EP Cores in 77 and 78 material.

1 65 -- 202021	3 65 -- 131321	5 65 -- 070721
2 65 -- 171721	4 65 -- 101021	

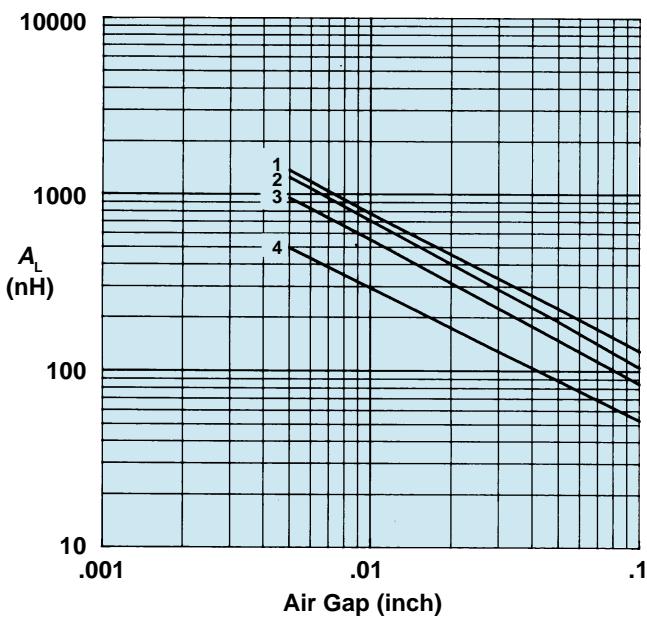


Figure 7 A_L vs. Gap for PQ Cores in 77 and 78 material.

1 66 -- 404021	3 66 -- 262521
66 -- 353521	66 -- 262021
2 66 -- 323021	4 66 -- 202021
66 -- 322021	66 -- 201621

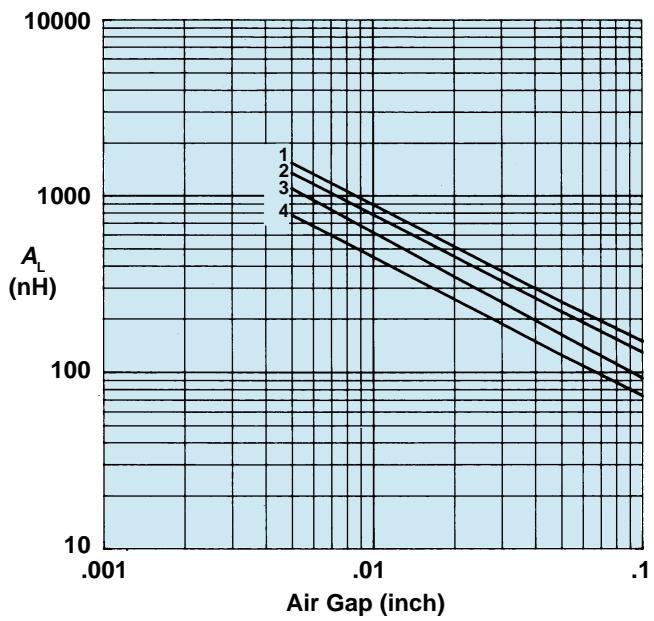


Figure 8 A_L vs. Gap for ETD Cores in 77 and 78 material.

1 95 -- 490002	3 95 -- 390002
2 95 -- 440002	4 95 -- 340002

Technical Information

DC Bias in Open Magnetic Cores

The discussion so far has been on core types that have a closed magnetic path, in which a small air gap has been inserted by either a ground gap or the use of shims. An open magnetic core can be thought of as a core with a very large fixed air gap. Since the air gap is determined by the core geometry and cannot be changed, the Hanna curves can not be used for these types of cores. Such cores as rods, slugs and bobbins can be used quite successfully in inductor designs that have relative low inductance values and can accommodate significant amounts of static currents.

The large air gap will forestall the saturation of this type of core, hence the inductance will not as easily decrease as a function of the dc ampere-turns. The Fair-Rite bobbins, listed on the pages 110 and 111 of the catalog, are specified to an inductance index or A_L with a tolerance of $\pm 10\%$ and also by a NI product of dc ampere-turns, which might reduce the A_L value but not more than 5%. For an inductor design the number of turns can be calculated

from the required inductance L and the inductance index of the bobbin. $N = \sqrt{L/A_L}$, (L in nH). The turns N times the direct current I will give the NI product, which should be less than the value quoted for the bobbin. For winding fit and dc resistance check, the same procedure is used as outlined in the example above, except here the W_a of the bobbin is the total available winding area. The graphs of Figure 9 show the effect of temperature on the inductance factor vs. dc bias characteristics of the 9677242409 bobbin. As can be seen from these curves, the decrease in inductance increases with temperature. The NI values listed in the catalog are at room temperature, and must be derated when operating at elevated temperatures. Open magnetic cores, rods, slugs and bobbins are used and designed into SCR and triac controls, speaker crossover networks and differential-mode input filters. They are also utilized for EMI suppression applications where relatively large direct currents are present and for output chokes in switched-mode power supplies.

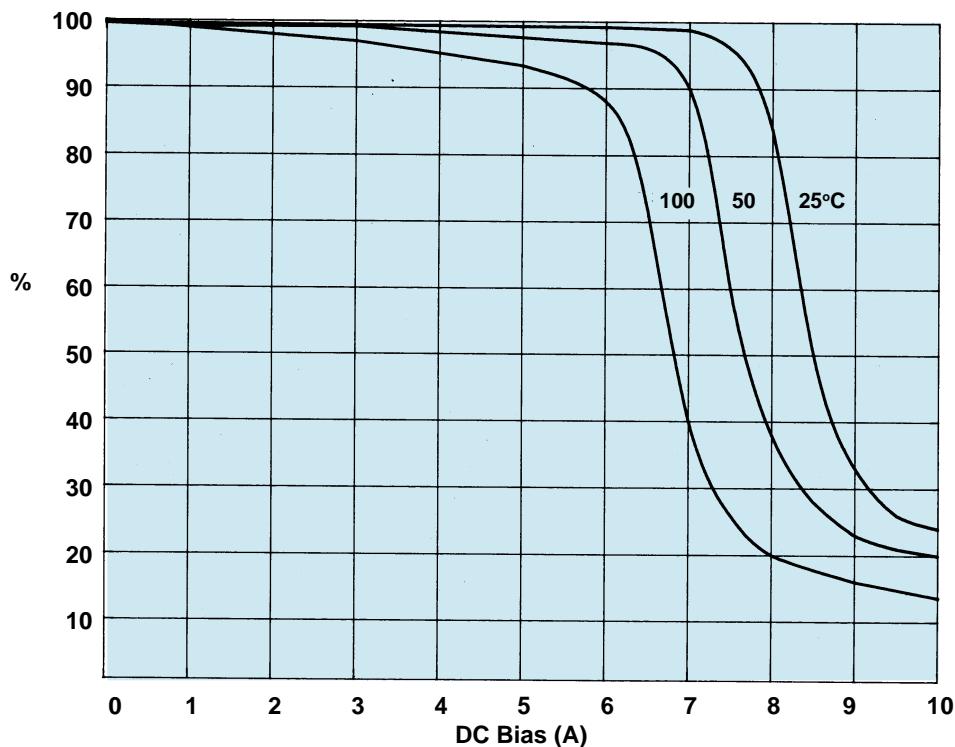


Figure 9 Percent of Original Inductance Factor vs. DC Bias and Temperature.

Technical Information

Use of Ferrites in Broadband Transformers

Introduction

Most of the magnetic information in this catalog is data obtained from cores wound with a single multi-turn-winding which forms an inductor. When a second winding is added on the core, the inductor becomes a transformer. Depending on the requirements, transformers can be designed to provide dc isolation, impedance matching and specific current or voltage ratios. Transformer designed for power, broadband, pulse, or impedance matching can often be used over a broad frequency spectrum.

In many transformer designs ferrites are used as the core material. This article will address the properties of the ferrite materials and core geometries which are of concern in the design of low power broadband transformers.

Brief Theory

Broadband transformers are wound magnetic devices that are designed to transfer energy over a wide frequency range. Most applications for broadband transformers are in telecommunication equipment where they are extensively used at a low power levels.

Figure 1 shows a typical performance curve of insertion loss as a function of frequency for a broadband transformer. The bandwidth of a broadband transformer is the frequency difference between f_2 and f_1 , or between f'_2 and f'_1 , and is a function of the specified insertion loss and the transformer roll-off characteristics.

It can be seen that the bandwidth is narrower for transformers with a steep roll-off ($f'_2 - f'_1$) than those with a more gradual roll-off ($f_2 - f_1$). Also in figure 1, the three frequency regions are identified.

The cutoff frequencies are determined by the requirements of the individual broadband transformer design. Therefore, f_1 can be greater than 10 MHz or less than 300 Hz. Bandwidths also can vary from a few hundred hertz to hundreds of MHz. A typical

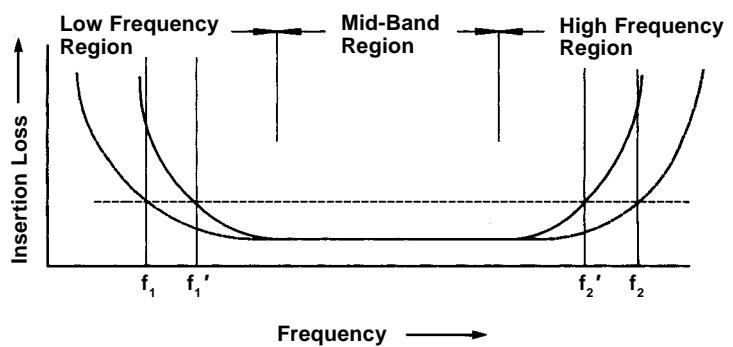


Figure 1 Typical Characteristic Curve of Insertion Loss vs. Frequency for a broadband transformer.

broadband transformer design will specify for the mid frequency range a maximum insertion loss and for the cutoff frequencies, f_1 and f_2 maximum allowable losses. Figure 2 is a schematic diagram of the lumped element equivalent circuit of a transformer, separating the circuit into an ideal transformer, its components and equivalent parasitic resistances and reactances. The secondary components, parasitics and the load resistance have been transferred to the primary side and are identified with a prime.

To simplify this circuit, the primary and secondary circuit elements have been combined and the equivalent reduced circuit is shown in Figure 3. The physical significance of the parameters are listed below the equivalent circuits. In the low frequency region the roll-off in transmission characteristics is due a lowering of the shunt impedance. The shunt impedance decreases when the frequency is reduced, which results in the increases level of attenuation. The impedance is mainly a function of the

Technical Information

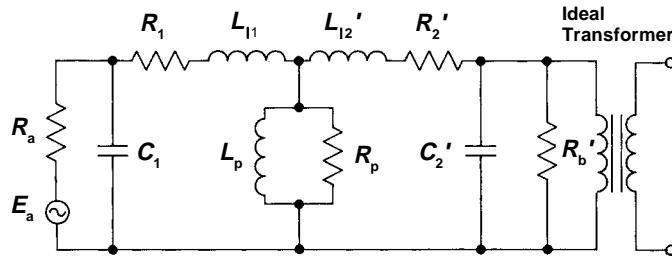


Figure 2 Lumped equivalent of a transformer.

E_a = source EMF

R_a = source resistance

C_1 = primary winding capacitance

R_1 = resistance of primary winding

L_{11} = primary leakage inductance

L_p = open circuit inductance of primary winding

R_p = shunt resistance that represents loss in core

Secondary parameters reflected to the primary side.

C_2' = secondary winding capacitance

R_2' = resistance of secondary winding

L_{12}' = secondary leakage inductance

R_b' = load resistance

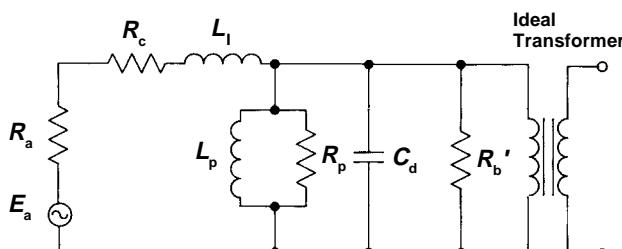


Figure 3 Simplified equivalent transformer circuit

$$C_d = C_1 + C_2'$$

$$R_c = R_1 + R_2'$$

$$L_i = L_{11} + L_{12}'$$

For other circuit parameters see figure 2.

primary reactance X_{LP} with a negligible contribution of the equivalent shunt loss resistance R_p . The insertion loss may therefore be expressed in terms of the shunt inductance:

$$A_i = 10 \log_{10} \left(1 + \left(\frac{R}{\omega L_p} \right)^2 \right) \text{ dB}$$

Where $R = R_a \times R_b' / R_a = R_b'$

For most ferrite broadband transformer designs, the only elements that are likely to effect the transmission at the mid-band frequency range are the winding resistances. The insertion loss for the mid-band frequency region due to the winding resistance may be expressed as:

$$A_i = 20 \log_{10} \left(1 + \frac{R_c}{R_a + R_b'} \right) \text{ dB}$$

Where $R_c = R_1 + R_2'$

In the higher frequency region the transmission characteristics are mainly a function of the leakage inductance or the shunt capacitance. It is often necessary to consider the effect of both of these reactances, depending upon the circuit impedance. In a low impedance circuit the high frequency droop due to leakage inductance is:

$$A_i = 10 \log_{10} \left(1 + \left(\frac{\omega L_i}{R_a + R_b'} \right)^2 \right) \text{ dB}$$

This high frequency droop in a high impedance circuit, due to the shunt capacitance, is as follows:

$$A_i = 10 \log_{10} \left(1 + (\omega C R)^2 \right) \text{ dB}$$

Reviewing the insertion loss characteristics for the three frequency regions, it can be concluded that the selection of ferrite material and core shape should result in a transformer design that yields the highest inductance per turn at the low frequency cutoff f_1 . This will result in the required shunt inductance for the low frequency region with the least number of turns. The low number of turns are desirable for low insertion loss at the mid-band region and also for low winding parasitics needed for good response at the high frequency cutoff f_2 .

Technical Information

Low and Medium Frequency Broadband Transformers

For broadband transformer applications the optimum ferrite is the material that has the highest initial permeability at the lower cutoff frequency f_c . Manganese zinc ferrites, such as Fair-Rite 77 or 73 material, are very suitable for low and medium frequency broadband transformers designs. As stated before, the transformer parameter that is most critical is the shunt reactance (ωL), which will increase with frequency as long as the material permeability is constant or diminishing at a rate less than the increase in frequency. This holds true even if a transformer is designed using a manganese zinc ferrite where f_c is at the higher end of the flat portion of the permeability vs. frequency curve. Although the whole bandpass lies in the area where the initial permeability is decreasing, yet the bandpass characteristics will be virtually unaffected. For broadband transformers that use a manganese zinc ferrite material the core geometry should be such as to minimize the R_{dc}/L ratio. In other words, the ratio of dc resistance to the inductance for a single turn should be a minimum. The range of pot cores, standardized by the International Electrotechnical Commission in document IEC 133, has been designed for this minimum R_{dc}/L ratio.* Other core shapes such as the EP cores and PQ cores can also be used in the design of these broadband transformers. Often the final core selection will also be influenced by such considerations as ease of winding, terminating and other mechanical design constraints of the transformer.

Broadband Transformers with a Superimposed Static Field

In transformer designs that have a superimposed direct current, gapped cores can be employed to overcome the decrease in the shunt inductance. Hanna curves can be used to aid in the design of inductive devices that carry a direct current. For more information see section "The Effect of Direct Current on the Inductance of a Ferrite Core" on page 26.

High Frequency Broadband Transformers.

Although there is no clear division between the frequency regions, for this article it is assumed that the high frequency broadband transformer designs use nickel zinc ferrites as the

preferred core material. This will typically occur for transformer designs where the bandpass lies wholly above 500 kHz. At these higher operating frequencies it becomes more important to consider the complex magnetic parameters of the core material, rather than use the simple core constants, such as A_L , recommended for low frequency designs.

Another important consideration is that high frequency transformers are generally used in low impedance circuits, which means that these designs require low shunt impedances. This can often be accomplished with a few turns, hence winding resistances are no longer an issue, and the design concept of minimizing R_{dc}/L is no longer required. The design will instead become focused on core shape and material for the required shunt impedance at f_c along with reducing leakage inductance of the winding. Since the material characteristics permeability and losses affect the shunt impedance these parameters need to be considered in high frequency broadband transformer designs. Figures 4, 5 and 6 are typical curves of impedance Z , equivalent parallel reactance X_p and equivalent parallel loss resistance R_p as a function of frequency. They are measured on the same multi-aperture core 28-002402, in 73, 43, 61 and 65 material, wound with a single turn through both holes. For high frequency broadband transformers the toroidal core shape becomes an attractive core geometry. The few turns that are often required can easily be wound on the toroid. However, windings that require only a few turns may give rise to problems in obtaining the desired impedance ratios. To minimize leakage inductance it is suggested that the primary and secondary windings be tightly coupled and where possible a bifilar winding be used.

An improvement in core performance over toroids can be obtained by the use of multi-aperture cores, which can be considered as two toroidal cores side by side. This core shape has a lower single turn winding length than the equivalent toroidal core with the same core constant C_1 , and will result in a wider bandwidth of the transformer design. Many broadband transformers have been designed utilizing nickel zinc ferrite toroids with good results. If bandwidth requirements cannot be met using toroids, multi-aperture nickel zinc cores should be considered.

The multi-aperture cores listed in this catalog on page 86, are available in the nickel zinc ferrite materials 65, 61 and 43 as well in the manganese zinc ferrite 73 material. Intrinsic material and part performance data are shown in Figures 7 through 32 for all these ferrite materials.

*Footnote: E. C. Snelling, *Soft Ferrites, Properties and Applications*.
2nd Edition 1988, Butterworths Publishing, Stoneham, MA.

Technical Information

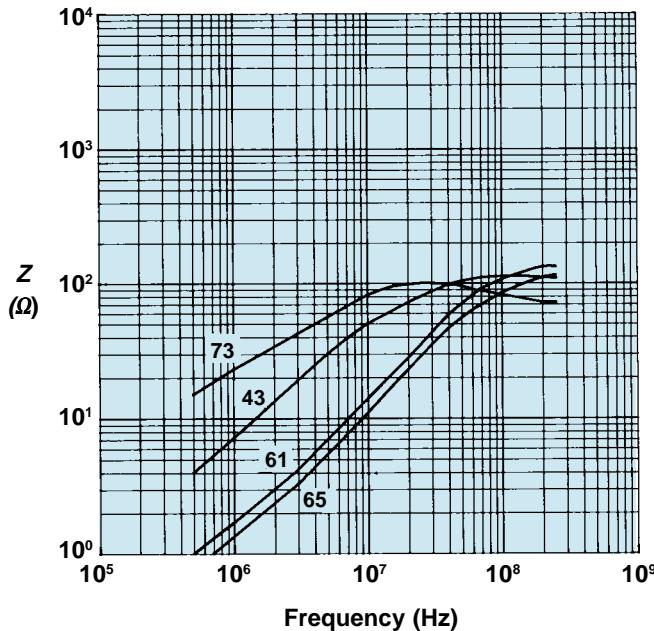


Figure 4 Impedance vs. Frequency for part number 28 - - 002402 in several materials.

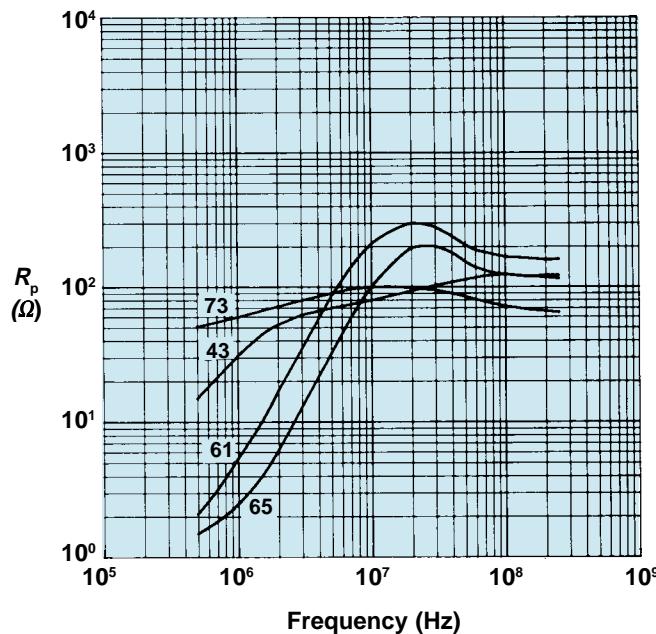


Figure 6 Parallel Resistance vs. Frequency for part number 28 - - 002402 in several materials.

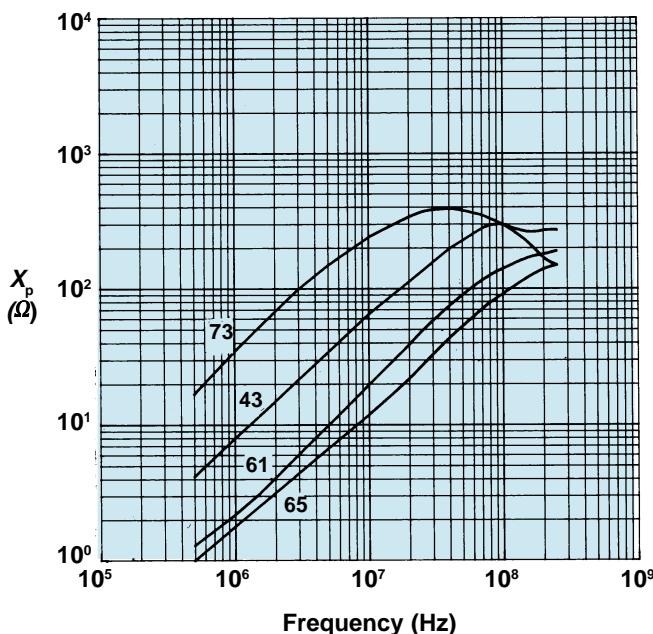


Figure 5 Parallel Reactance vs. Frequency for part number 28 - - 002402 in several materials.

Summary

The low cutoff frequency f_1 is the single most important factor in the ferrite material selection. The material with the highest initial permeability at f_1 is the recommended choice.

Manganese zinc ferrites, 73 and 77, can be used to a cutoff frequency f_1 of 500 kHz. Above this frequency use a nickel zinc ferrite, again depending upon the frequency f_1 , select 65, 61 or 43 material.

For low and medium frequency transformers the optimum core shape should provide the lowest dc resistance per unit of inductance. If there is a superimposed dc present the use of gapped cores and Hanna curves is suggested. For high frequency designs, use nickel zinc ferrite. The toroidal and multi-aperture cores are the recommended core configurations.

The number of turns should be kept to a minimum to reduce leakage inductance and self-capacitance of the windings. Wind primary and secondary windings tightly coupled or as bifilar windings to lower leakage inductance.

The Bead, Balun and Broadband Kit II, part number 0199000011, contains a variety of components suited for broadband transformer design evaluations, see page 84.

Typical Performance Data

Material 65

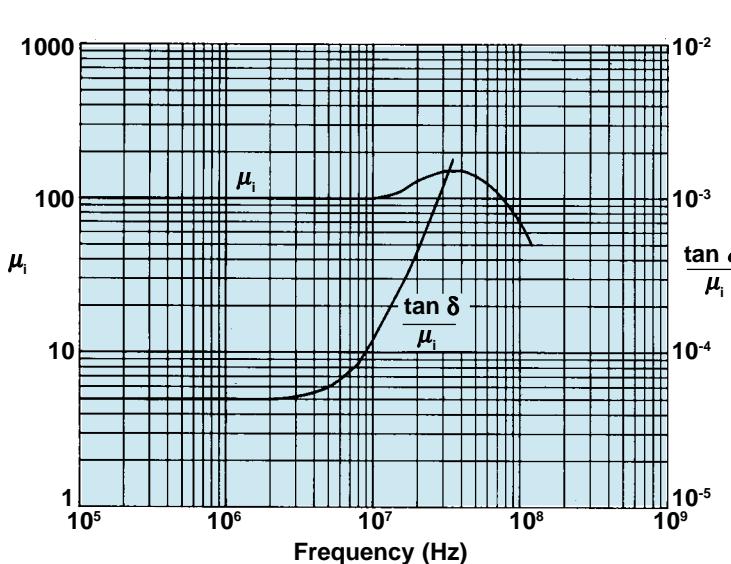


Figure 7 Initial Permeability and Loss Factor vs. Frequency.

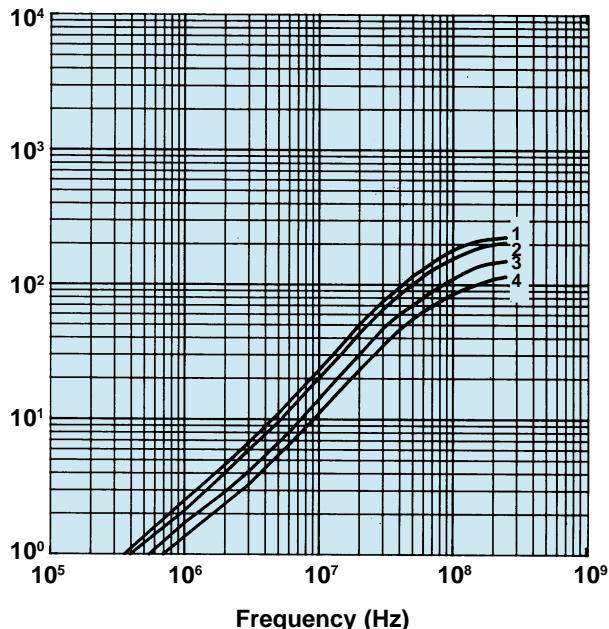


Figure 8 Impedance vs. Frequency of multi-aperture cores in 65 material.

1 2865003102 3 2865003002
2 2865000202 4 2865002402

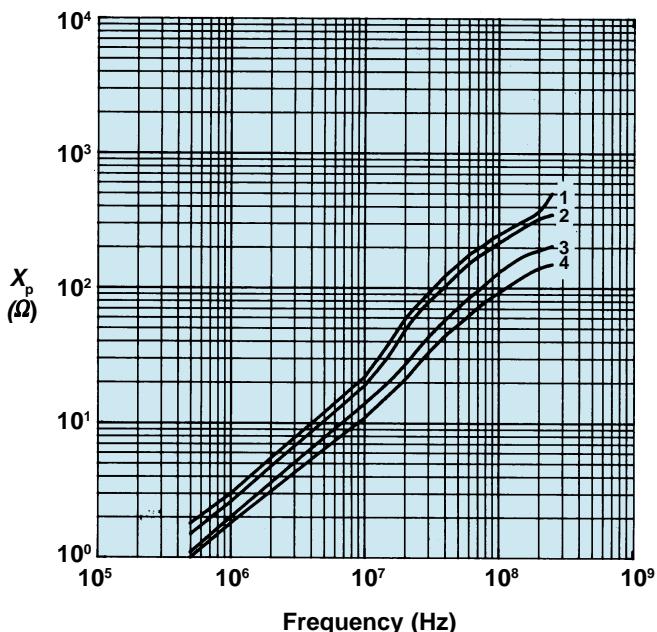


Figure 9 Parallel Reactance vs. Frequency of multi-aperture cores in 65 material.

1 2865003102 3 2865003002
2 2865000202 4 2865002402

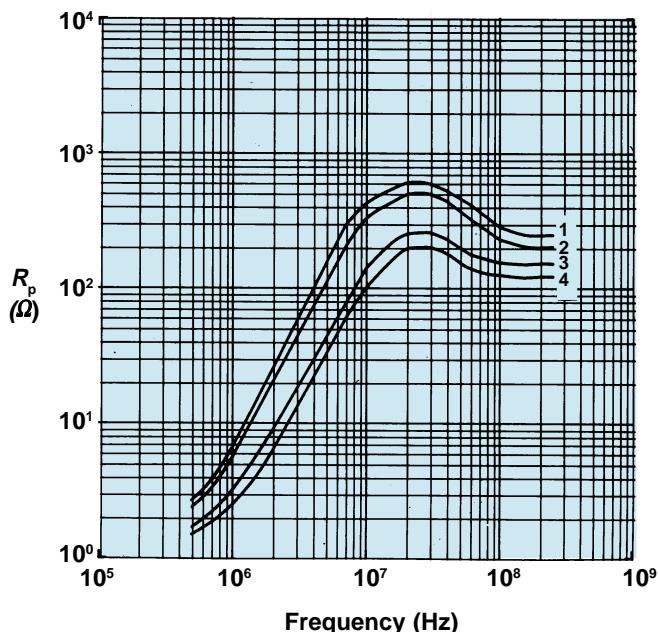


Figure 10 Parallel Resistance vs. Frequency of multi-aperture cores in 65 material.

1 2865003102 3 2865003002
2 2865000202 4 2865002402

Typical Performance Data

Material 61

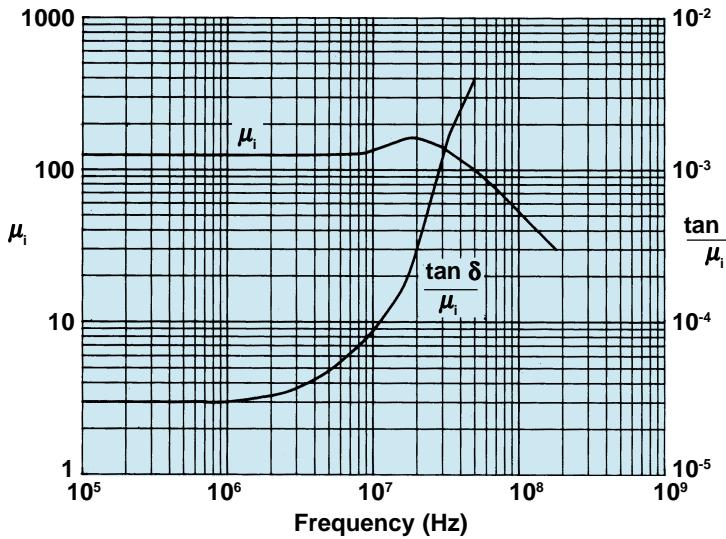


Figure 11 Initial Permeability and Loss Factor vs. Frequency.

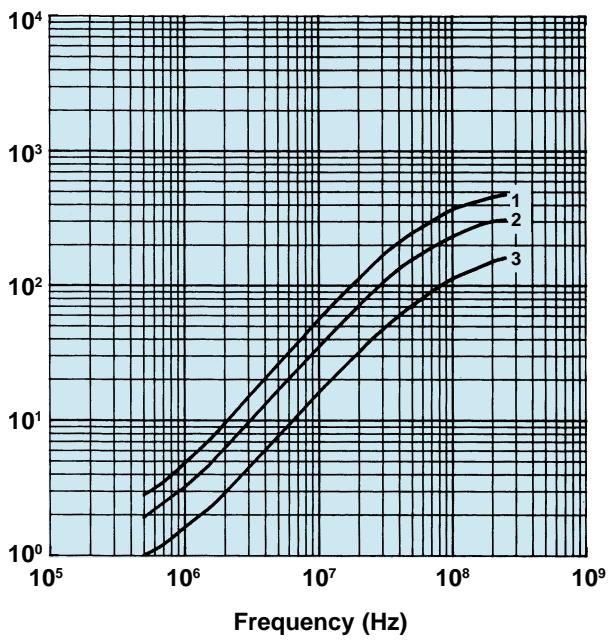


Figure 12 Impedance vs. Frequency of multi-aperture cores in 61 material.

1 2861006802 3 2861001802
2 2861001702

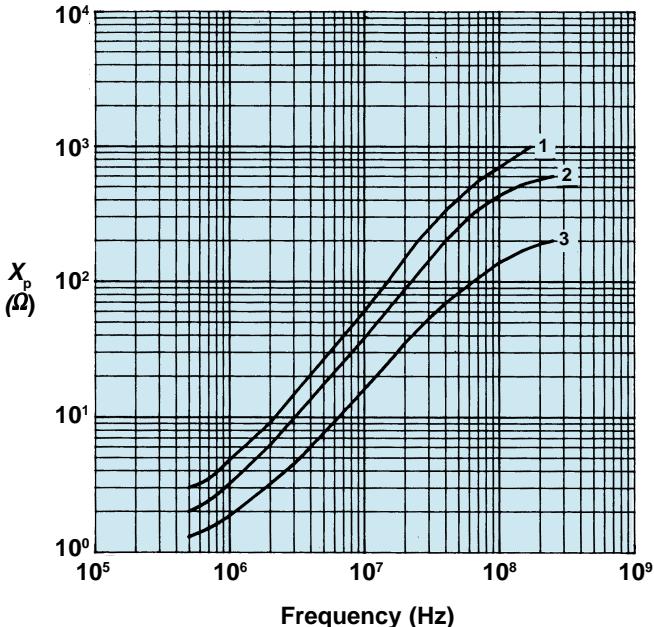


Figure 13 Parallel Reactance vs. Frequency of multi-aperture cores in 61 material.

1 2861006802 3 2861001802
2 2861001702

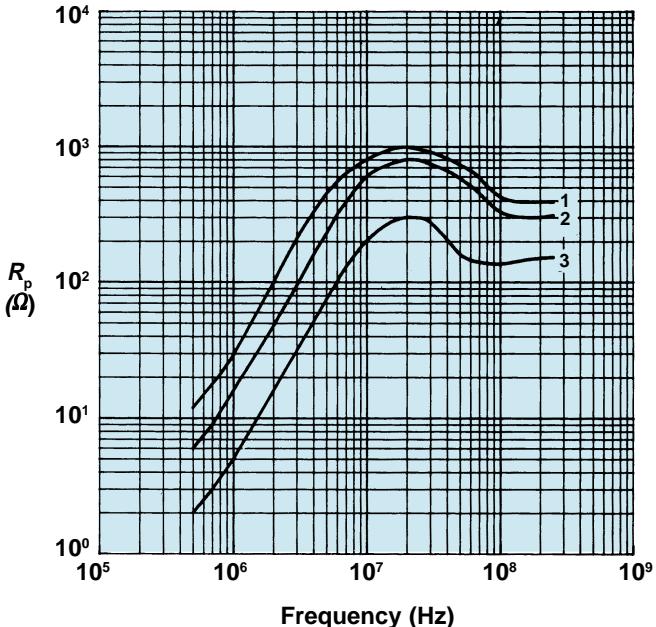


Figure 14 Parallel Resistance vs. Frequency of multi-aperture cores in 61 material.

1 2861006802 3 2861001802
2 2861001702

Typical Performance Data

Material 61

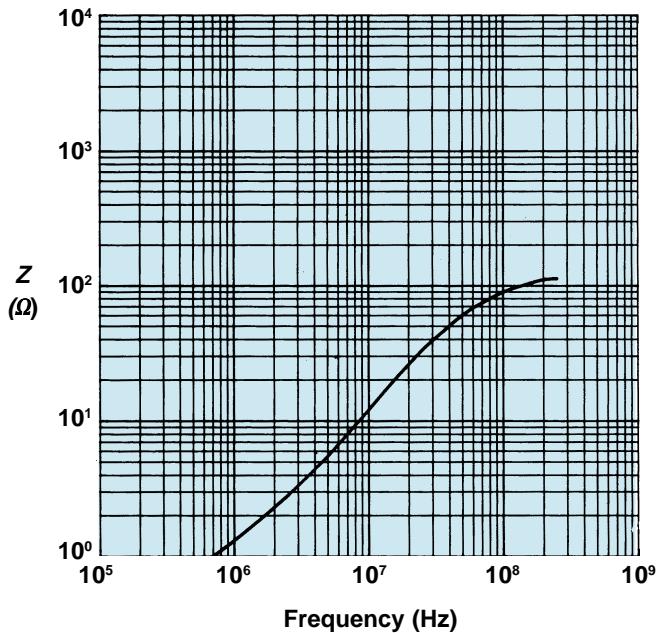


Figure 15 Impedance vs. Frequency of the 12.7 mm OD shield bead 2661801102.

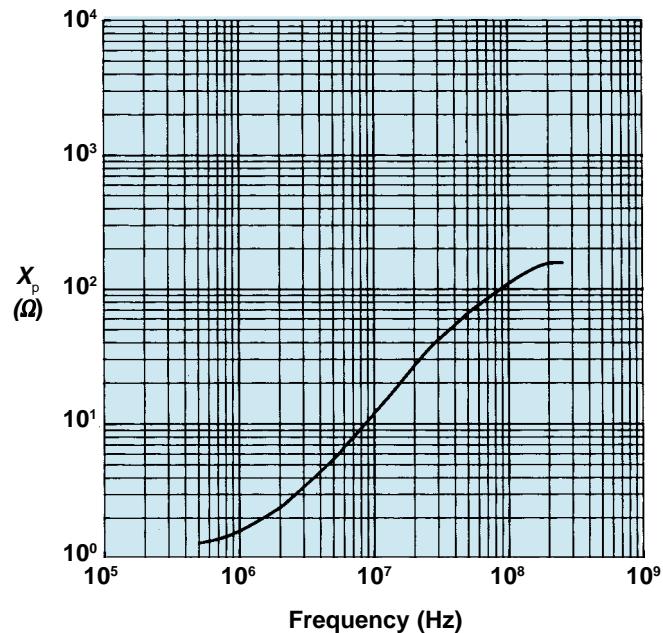


Figure 16 Parallel Reactance vs. Frequency of the 12.7 mm OD shield bead 2661801102.

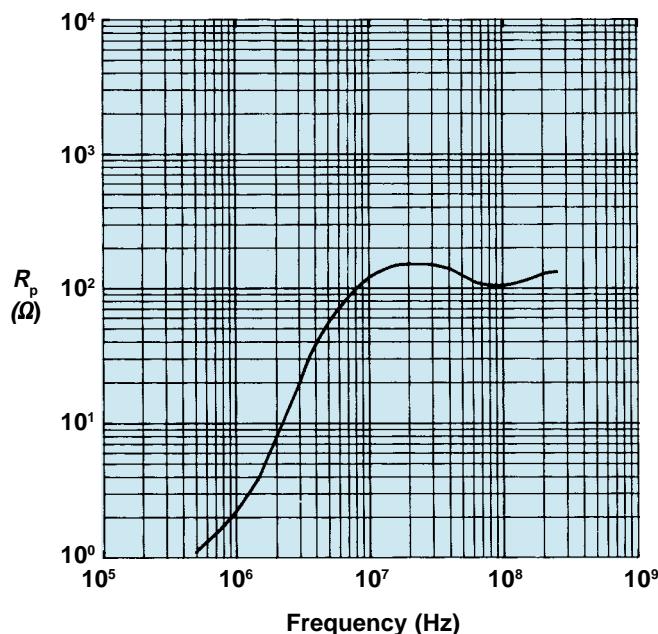


Figure 17 Parallel Resistance vs. Frequency of the 12.7 mm OD shield bead 2661801102.



Typical Performance Data

Material 43

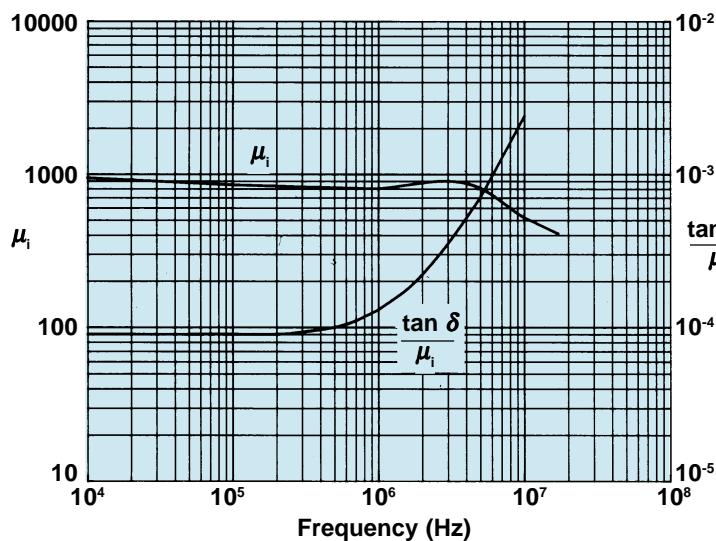


Figure 18 Initial Permeability and Loss Factor vs. Frequency.

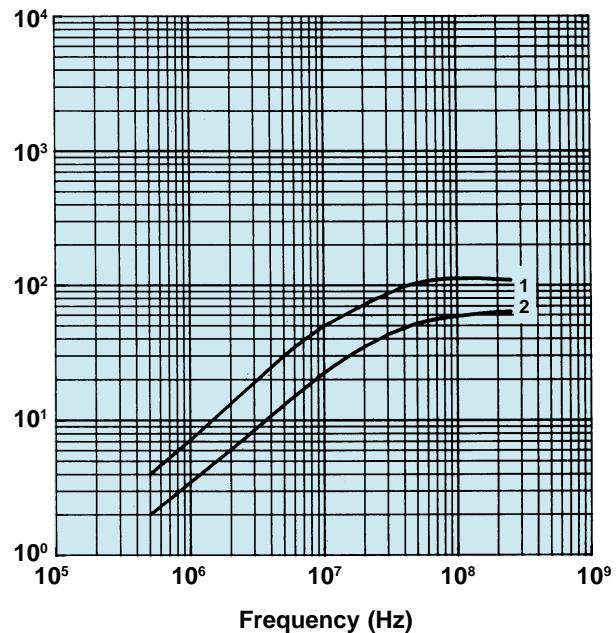


Figure 19 Impedance vs. Frequency of multi-aperture cores in 43 material.

1 2843002402 2 2843002302

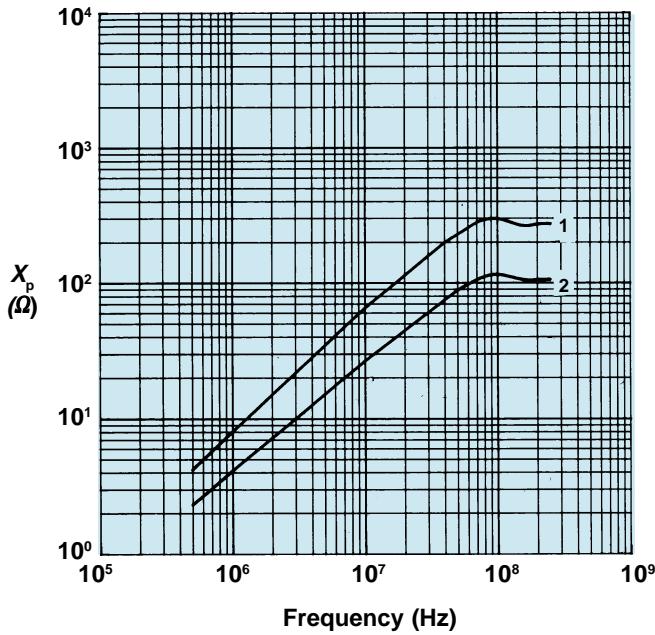


Figure 20 Parallel Reactance vs. Frequency of multi-aperture cores in 43 material.

1 2843002402 2 2843002302

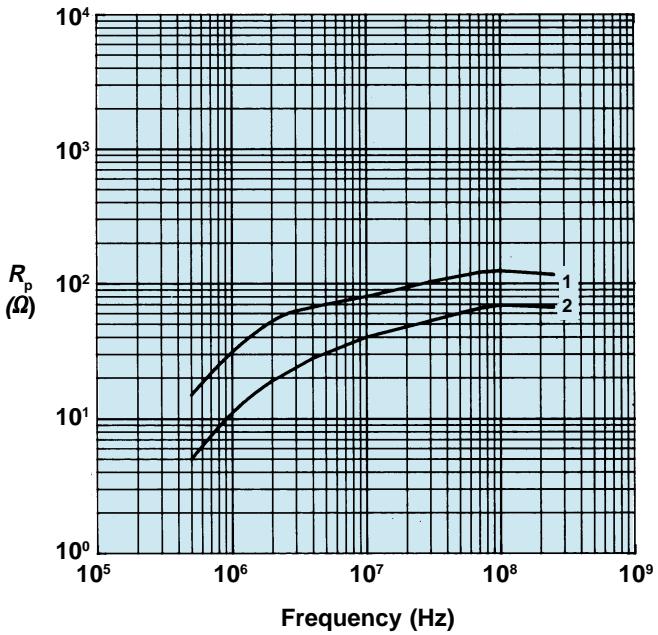


Figure 21 Parallel Resistance vs. Frequency of multi-aperture cores in 43 material.

1 2843002402 2 2843002302

Typical Performance Data

Material 43

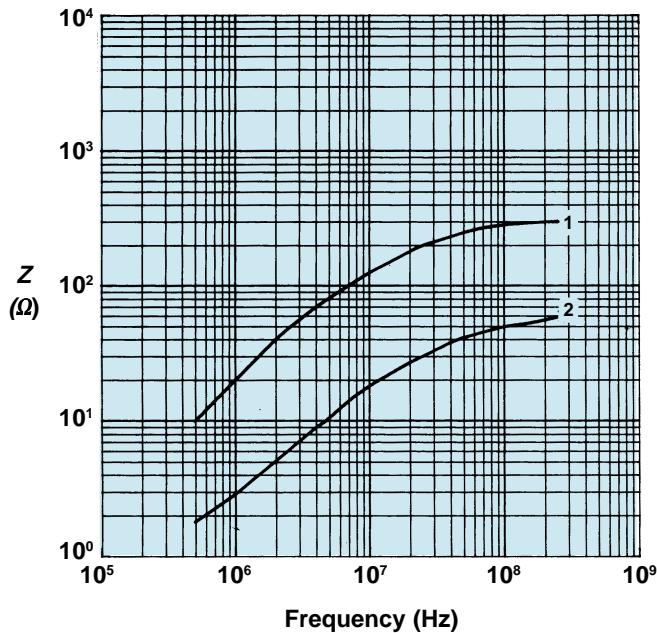


Figure 22 Impedance vs. Frequency of large shield beads in 43 material.

1 28435400002 2 2843002402

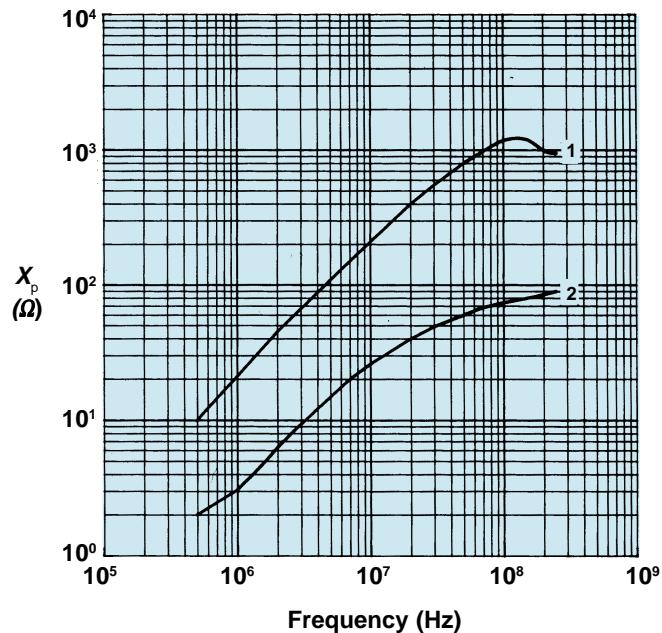


Figure 23 Parallel Reactance vs. Frequency of large shield beads in 43 material.

1 28435400002 2 2843002402

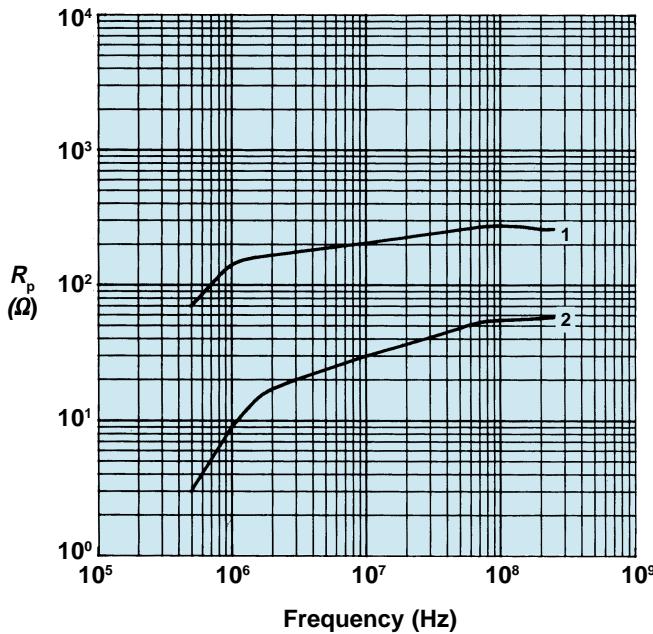


Figure 24 Parallel Resistance vs. Frequency of large shield beads in 43 material.

1 28435400002 2 2843002402



Typical Performance Data

Material 73

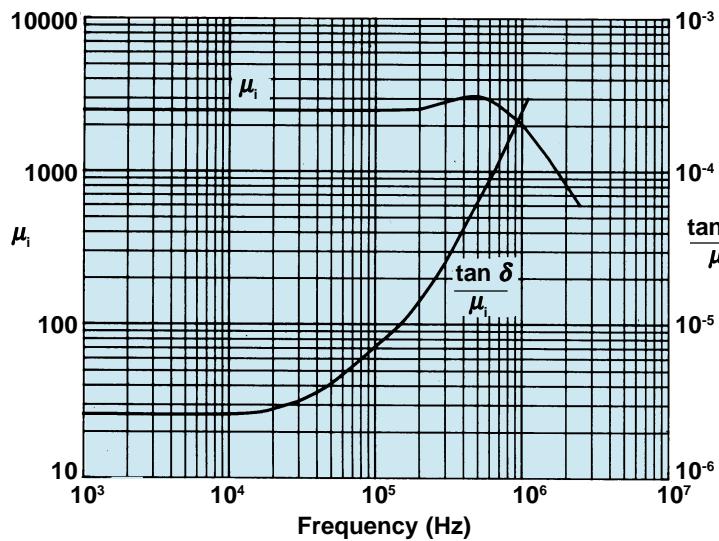


Figure 25 Initial Permeability and Loss Factor vs. Frequency.

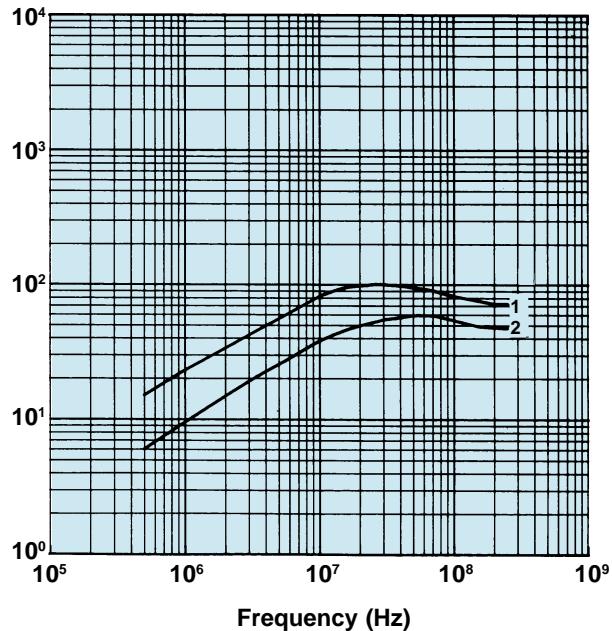


Figure 26 Impedance vs. Frequency of multi-aperture cores in 73 material.

1 2873002402 2 2873002302

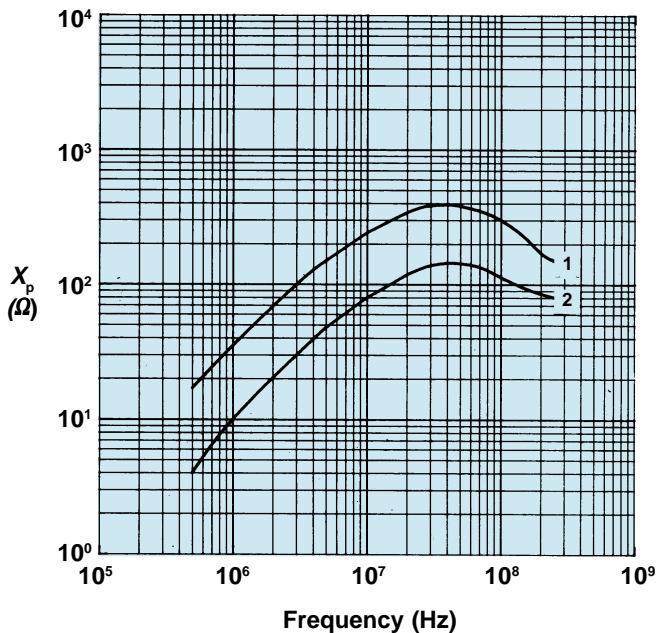


Figure 27 Parallel Reactance vs. Frequency of multi-aperture cores in 73 material.

1 2873002402 2 2873002302

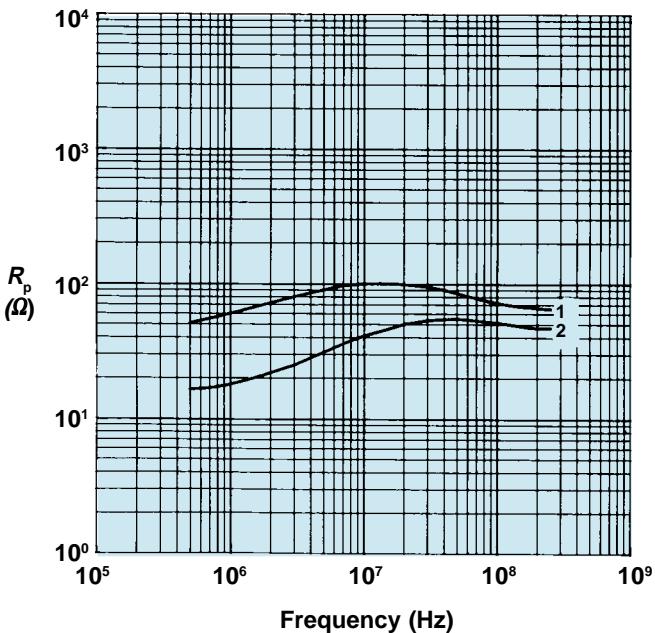


Figure 28 Parallel Resistance vs. Frequency of multi-aperture cores in 73 material.

1 2873002402 2 2873002302

Typical Performance Data

Material 77

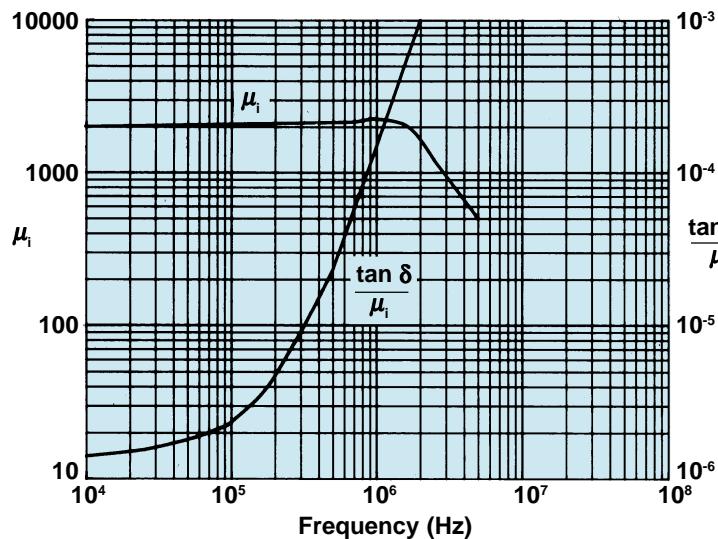


Figure 29 Initial Permeability and Loss Factor vs. Frequency.

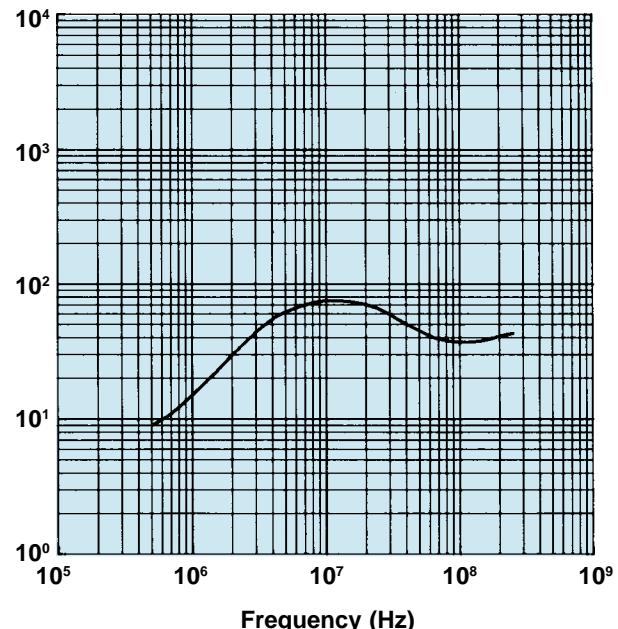


Figure 30 Impedance vs. Frequency of the shield bead 2677006303.

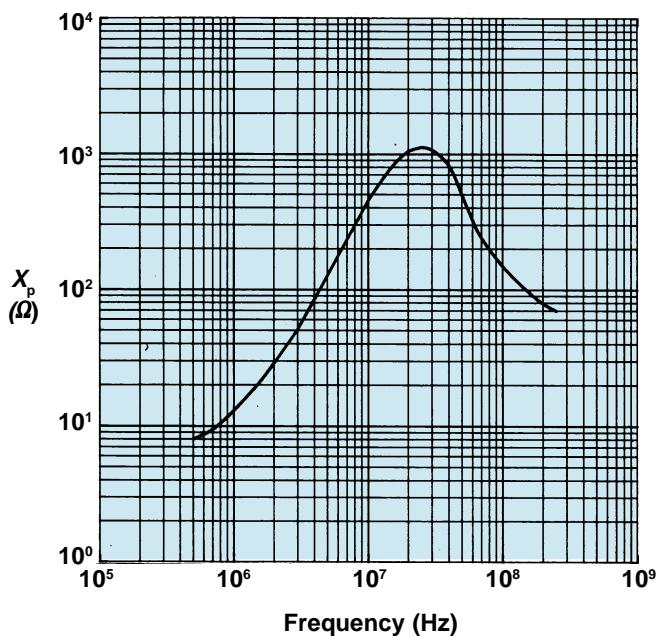


Figure 31 Parallel Reactance vs. Frequency of the shield bead 2677006303.

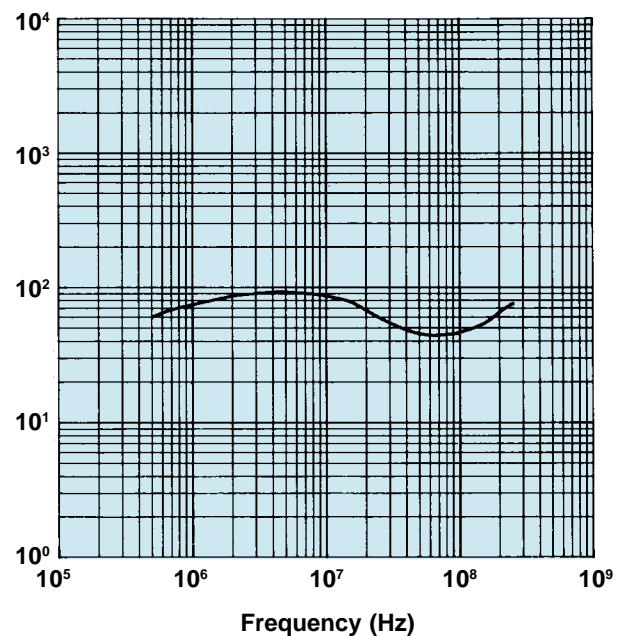


Figure 32 Parallel Resistance vs. Frequency of the shield bead 2677006303.

Technical Information

How to Choose Ferrite Components for EMI Suppression.

Introduction

The following pages will focus on Soft Ferrites used in the application of electromagnetic interference (EMI) suppression. Although the end use is an important issue and some applications are mentioned, this technical section is not intended to be a design manual, but rather, an aide to the designer in understanding and choosing the optimum ferrite component for the particular application. The reader will discover that ferrite suppressor cores are not too difficult to understand, are very simple to use, in either initial designs or retrofits, and are comparatively economical in both price and space. Ferrite suppressors have been successfully employed for attenuating EMI in computers and related products, switching power supplies, electronic automotive ignition systems, and garage doors openers, to name just a few.

Use of Ferrite Suppressor Cores

The United States was one of the first countries to recognize the potential problems caused by electromagnetic pollution. As a result the FCC was charged with the responsibility of promulgating rules and regulations to control and enforce limits on high frequency interference.

	Radiated Emissions		Conducted Emissions	
	Frequency of Emission (MHz)	Field Strength (microvolts/meter)	Frequency of Emission (MHz)	Signal (microvolts)
Class A	30-88	90 @ 10m	0.45 - 1.705	1000
	88-216	150 @ 10m	1.705 - 30.0	3000
	216-960	210 @ 10m		
	Above 960	300 @ 10m		
Class B	30-88	100 @ 3m	0.45 - 30	250
	88-216	150 @ 3m		
	216-960	200 @ 3m		
	Above 960	500 @ 3m		

Figure 1 FCC Radiation Limits for class A & B equipment.

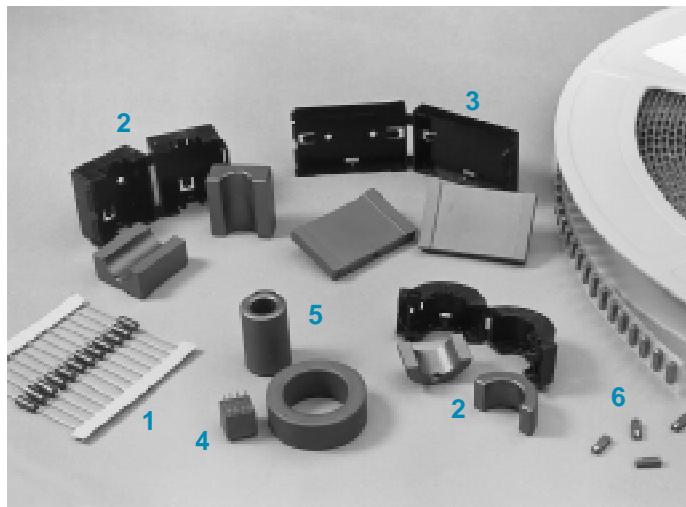


Figure 2, 3 Variety of EMI Suppression Cores including: (1) Beads on Leads, (2) Split Round Cable Suppression Cores and Cases, (3) Split Flat Cable Suppression Cores and Cases, (4) Printed Circuit (PC) Beads, (5) Toroidal Type Shield Beads, (6) Surface-Mount (SM) Beads, (7) on Reel, (8) Wound Beads, (9) Connector Suppression Discs and Plates and (10) One of five Engineering Kits containing a Large Variety of Samples of EMI Suppressor Cores.

Technical Information

Figure 1 shows the current radiation limits as defined by FCC Rules Part 15, for class A (industrial) and class B (mass-market) equipment.

Contrary to a decade ago when these regulations were first enforced and designing for EMI protection was often an afterthought rather than a forethought, a major portion of today's circuitry is incorporating EMI safeguards in the initial design. Many approaches can be used to comply with design or specification limits for EMI. Attention to basic circuit design, component layout, shielded enclosures and other use of shielding materials may be considered. For reducing or eliminating interference on printed circuit boards in wiring and cables, ferrite components have been used very successfully for decades. Figures 2 and 3 are photographs of a representative sampling of Fair-Rite suppressor cores.

There are basically three different ways to use ferrites as suppressors of unwanted signals, conducted or radiated. The first, and least common, is as actual shields where ferrite is used to isolate a conductor, component or circuit, from an environment of radiated stray electromagnetic fields. In both the second and the third application, ferrites are used as components to protect against conducted EMI. The second application is in conjunction with a capacitive element to create a low pass filter that is basically inductance-capacitance (LC) at low frequencies and dissipative at higher frequencies. The third and most common use will be addressed in this section of the catalog. In this case the cores are used alone on component leads or in board level circuitry either to prevent any parasitic oscillations or to attenuate unwanted signal pickup or transmissions which might travel along component leads or interconnecting wires, traces, or cables.

The Magnetics

Although permeability and quality factor play a role in the performance of a ferrite EMI suppressor, in virtually all instances, the frequency of usage puts these parameters beyond the point of meaningful definition, and as will be discussed later, the cores impedance is specified instead.

The permeability of a material is a complex parameter consisting of a real and an imaginary part. The real component represents the reactive portion and the imaginary component represents the losses. These may be expressed as series components (μ_s' , μ_s'') or parallel components (μ_p' , μ_p'').

The curves in Figure 4, are typical graphs of the permeability (μ_s') vs. frequency for various ferrite materials. The curves of Figure 5 are plots of loss factor ($\tan \delta / \mu_i$) in parts per million (ppm) vs. frequency for the same materials. The total loss tangent ($\tan \delta$) is the reciprocal of the Q factor and is a measure of the energy lost or incurred as the magnetization alternates. The real part of the permeability (μ_s') of these materials range from 40 to 10,000. In almost all cases μ_s' of the material first remains constant with frequency, then rises to a maximum value after which it falls off sharply. The loss component (μ_s'') rises to a peak as μ_s' falls. This is principally due to the ferrimagnetic resonance or spin

precession resonance. It should be noted that the higher the permeability the lower the frequency at which this occurs. This was first observed by J. L. Snoek and given the relationship:

$$f_{\text{res}} = \gamma M_{\text{sat}} / 3\pi(\mu_i - 1) \text{ Hz} \quad \text{eq.[1]}$$

where: f_{res} = frequency at which μ_s'' is maximum

γ = gyromagnetic ratio $\sim 0.22 \times 10^6 \text{ A}^{-1}\text{m}$

μ_i = initial permeability

$M_{\text{sat}} \sim 250-350 \times 10^3 \text{ Am}^{-1}$

this same relationship can also be approximated by:

$$f_{\text{max}} \sim B_{\text{sat}} / \mu_i \text{ MHz} \quad \text{eq.[2]}$$

where: $B_{\text{sat}} \sim 3500 - 4500 \text{ gauss}$

Here f_{max} is the frequency limit of useful core inductance, not to be confused with maximum usable frequency for attenuation applications.

Figure 6 represents curves of impedance vs. frequency for the same ferrite materials in figures 4 and 5. Comparison of the three graphs shows that as the permeability decreases, the losses increase, and the impedance rises to a maximum, then either levels off or declines.

The impedance of a wound ferrite core is considered to be a series combination of the inductive reactance, ($j\omega L_s$) and the equivalent loss resistance, (R_s), both of which are frequency

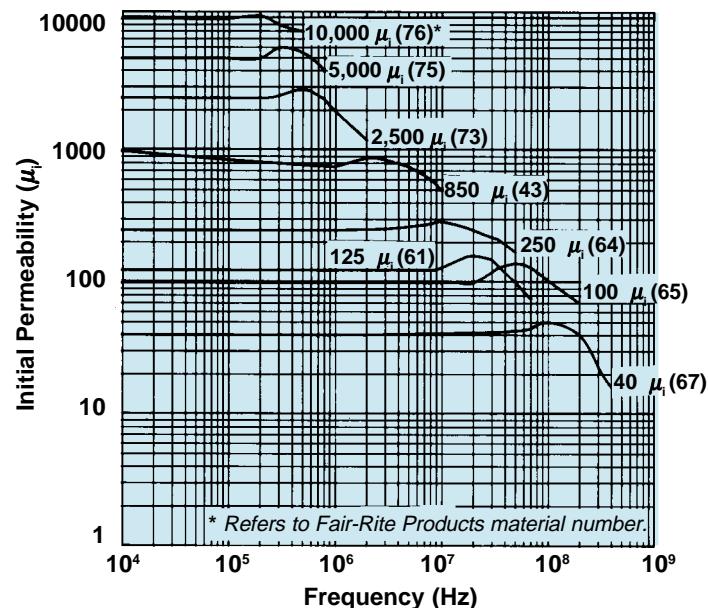


Figure 4 Initial Permeability vs. Frequency for various ferrite materials. Measured on Fair-Rite PN 26--000101 using HP 4275A and HP 4191A.

Technical Information

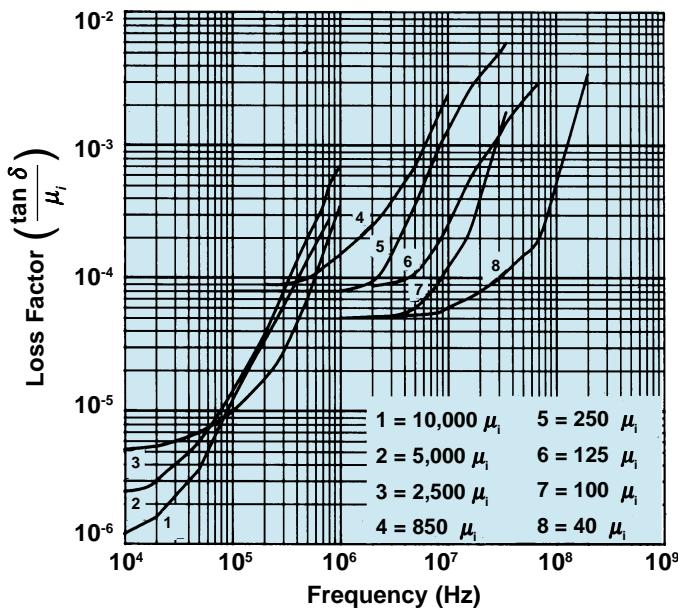


Figure 5 Loss Factor vs. Frequency for same the ferrite materials as in Figure 4. Measured on Fair-Rite PN 26-000101 using HP 4275A and HP 4191A.

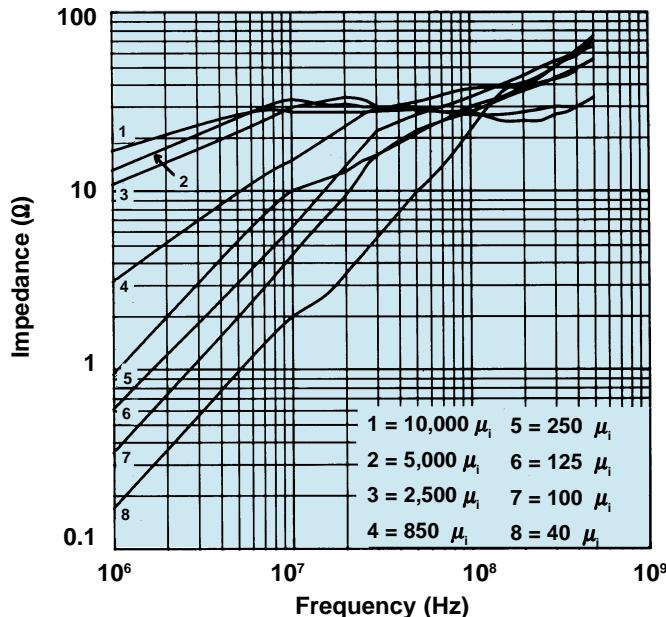


Figure 6 Impedance vs. Frequency for same ferrite materials as in Figures 4 and 5. Measured on Fair-Rite PN 26-000101 using HP 4191A.

dependent. At low frequencies the impedance of the suppressor core is primarily the inductive reactance, which is a function of the material's permeability, and unwanted signals are mostly reflected. As the frequency increases, the inductive reactance decreases. Even so, the total impedance increases due to the increasing losses, and unwanted signals are absorbed. Figure 7 is the simplest representation of the equivalent circuit of a ferrite core, an inductive reactance in series with a resistor.

Figure 8 is the vector representation of the relationship between the components of the complex permeability and the components of the complex impedance of a ferrite core.

The following equations relate the series impedance and the complex permeability:

$$Z = j\omega L_s + R_s = j\omega L_o(\mu_s' - j\mu_s'') \text{ ohm} \quad \text{eq.[3]}$$

so that

$$\omega L_s = \omega L_o \mu_s' \text{ ohm} \quad \text{eq.[4]}$$

$$R_s = \omega L_o \mu_s'' \text{ ohm} \quad \text{eq.[5]}$$

where: L_o = Air Core Inductance

$$\text{and } \tan \delta = \frac{R_s}{\omega L_s} = \frac{\mu_s''}{\mu_s'} = \frac{1}{Q} \quad \text{eq.[6]}$$

$$\tan \Phi = \frac{\omega L_s}{R_s} = Q \quad \text{eq.[7]}$$

$$Z = [(\omega L_s)^2 + R_s^2]^{1/2} \text{ ohm} \quad \text{eq.[8]}$$

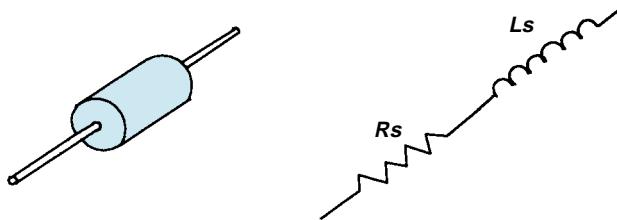


Figure 7 Figure 8 is the simplest representation of the equivalent circuit of a ferrite core, an inductor in series with a resistor.

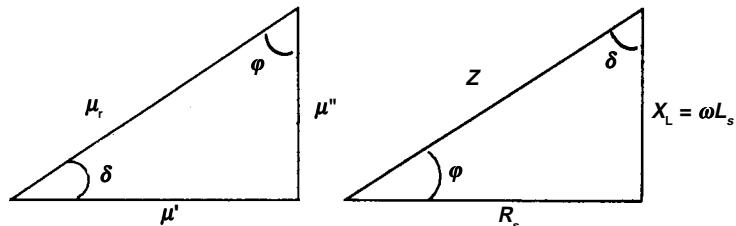


Figure 8 Vector relationship between real and imaginary components of impedance, complex permeability, series resistance and inductive reactance.

Technical Information

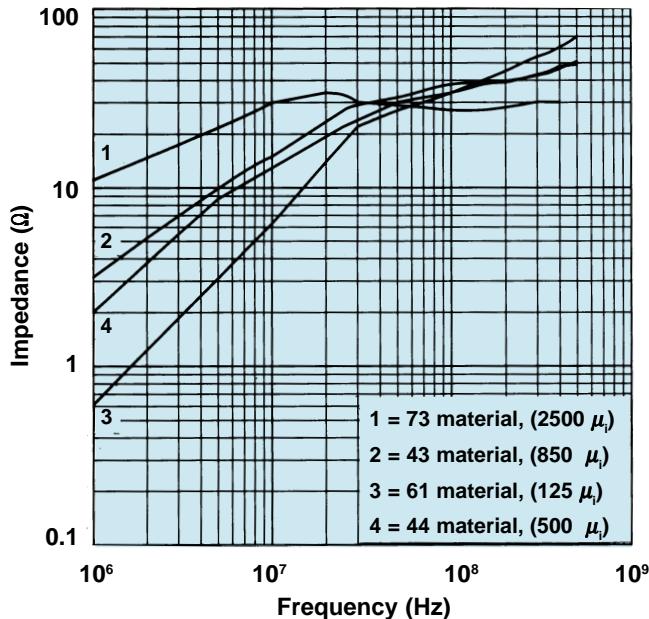


Figure 9 Impedance vs. Frequency for Fair-Rite Products four major suppressor materials. Measured on Fair-Rite PN 26---000101 bead using HP 4191A.

How to Choose the Right One

The designer or the retrofitter choosing the ferrite for optimum performance in combatting EMI, should know the following:

1. The frequency of the unwanted signals.
2. The source of the EMI.
3. Environmental conditions, temperature, and field strengths, ac and dc.
4. If high resistivity is required because of multiple turns, conductor pins in a connector filter plate or position in the circuit.
5. The circuit source and load impedances.
6. How much attenuation is required.
7. The allowable space on the board.

The Material

The first task is choosing the best ferrite material. This is based on the frequency or frequency range of the interference that must be suppressed.

Although most manufacturers of ferrite cores produce more than ten materials, only a select few have been offered for use in the suppression of EMI. The impedance vs. frequency curves for Fair-Rite's four major suppressor materials are shown in Figure 9. 73 material is a high permeability, $2500\mu_i$, low volume resistivity (10^2

ohm-cm), manganese zinc material, which is the material of choice for suppressing signals of 30 MHz or less. A "wideband" suppressor material, 43, is a medium permeability, $850\mu_i$, higher resistivity (10^5 ohm-cm) nickel zinc material, designed for suppression of signals between 25 and 200 MHz. The third material, 61, is a low permeability, $125\mu_i$, high resistivity (10^8 ohm-cm) nickel zinc material that is recommended for use at frequencies above 200 MHz. The fourth material, 44, is similar in many respects to 43 material. It provides much higher volume resistivity (10^9 ohm-cm), but somewhat lower impedance over the same frequency range.

After comparing Figure 9 with Figure 6 it becomes obvious why manufacturers have limited production to several choice materials. Simply stated, why offer eight materials, when three or four will cover the same frequency range effectively?

Covering the broadest frequency range with several materials is economical for both the manufacturer and the consumer, but if the application frequency is specific, rather than over this range, the most effective material may not be one of those offered. As an example, if optimum attenuation must be achieved at between 1 and 10 MHz, a 5000 or 10,000 permeability material could be much more effective than the standard 2500 permeability. Figure 10 is the impedance vs. frequency curve for the same bead in three different materials. Comparison of the impedance curves for these three materials reveals that the impedance of the 10,000 permeability material is superior up to 6 MHz, at which point the 5000 permeability material becomes more effective and at approximately 14 MHz,

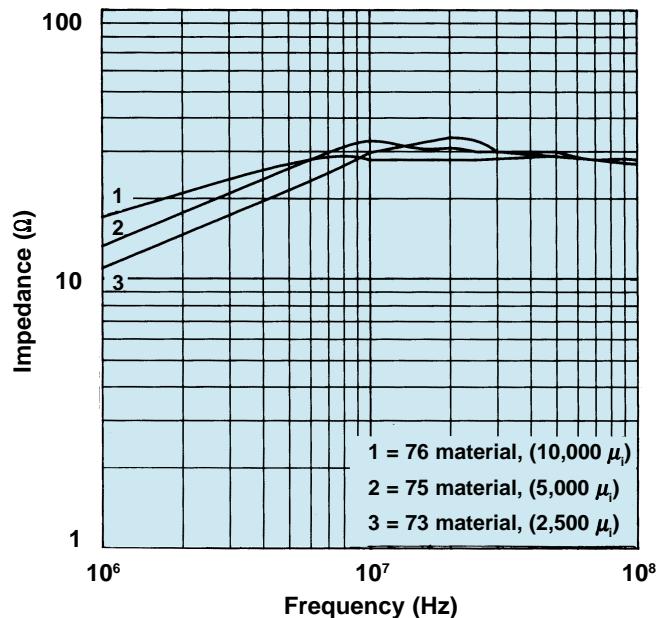


Figure 10 Impedance vs. Frequency for Fair-Rite Products three high permeability materials demonstrating the low frequency impedance. Measured on Fair-Rite PN 26---000101 bead using HP 4191A.

Technical Information

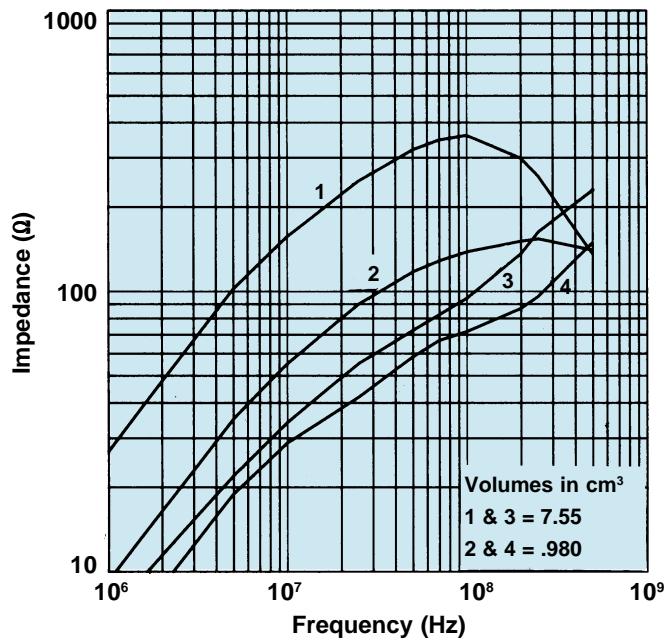


Figure 11 Impedance vs. Frequency for Fair-Rite shield beads, in the same material, two each with the same volume using HP 4191A.

the standard 2500 permeability material takes over. Therefore, if the requirement is for maximum attenuation at below 15 MHz and the ferrite manufacturer doesn't offer the higher permeability material in its standard suppressor line, try to get samples.

Generally speaking, the higher the permeability, the lower the optimum attenuation frequency, and conversely, the lower the permeability, the higher the attenuation frequency. This is frequency limited at both ends, since low frequency attenuation is reflective and high frequency attenuation is limited by the core and circuit resonance.

The Core

Once the material has been chosen, the size and shape of the core should be selected.

Figure 11 is a set of curves of impedance vs. frequency for four different beads, in the same material, two each with the same volume. Figure 12 is a set of curves of impedance vs. frequency for the same material, with different volumes. These curves show that increasing the cores volume does not guarantee an increase in impedance.

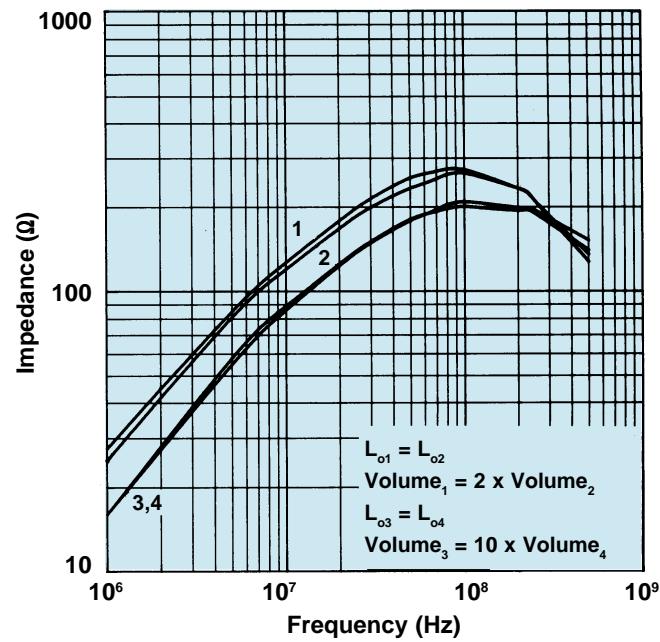


Figure 12 Impedance vs. Frequency for Fair-Rite shield beads, in the same material, all with different volumes. Two each with the same L_o using HP 4191A.

The same relationship that exists between the low frequency inductance factor (A_L) of a core and the core's initial permeability, can be used to approximate a core's impedance. This relationship is the core's air core inductance or L_o . It can be used as a proportion between two cores of the same material at the same frequency to approximate the impedance of one, knowing the impedance of the other. It is valid only below the resonant frequency, which is a function of the material and geometry of the core and/or winding/circuit conditions. The relationship is:

$$Z = K \times L_o$$

$$\text{Toroidal } L_o = .046 \times N^2 \times \log_{10}(\text{OD}/\text{ID}) \times Ht \times 10^{-8} \text{ H}$$

$$Z = .046 K \times N^2 \times \log_{10}(\text{OD}/\text{ID}) \times Ht \times 10^{-8} \text{ ohm eq.[9]}$$

All dimensions are in mm.

$$\text{where: } K = Z/L_o \text{ (ohm/H) } 10^8$$

$$N = \text{Number of turns} = 1$$

This is a very useful tool for maximizing the impedance of a core within the allowable space, after the best material has been chosen. It reconfirms the fact that in most cases greater impedance will be obtained by increasing the height of the core rather than the diameter for the same increase in volume.

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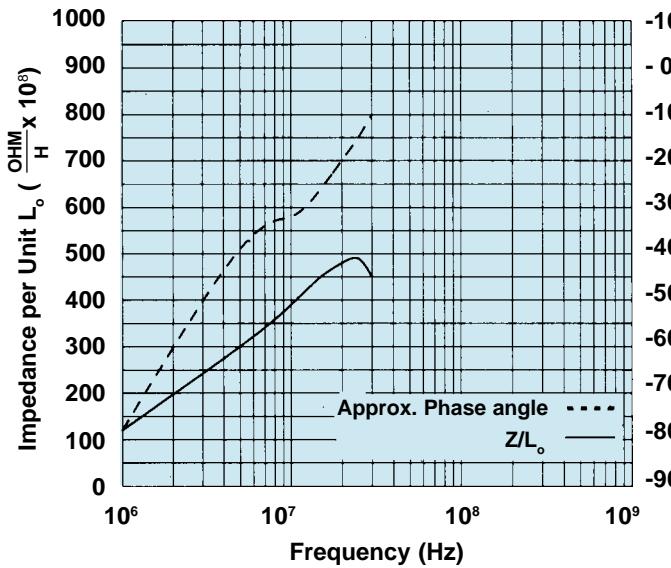


Figure 13 Nominal Impedance Per Unit L_o and Average Phase Angle vs. Frequency for Fair-Rite 73 material using HP 4191A.

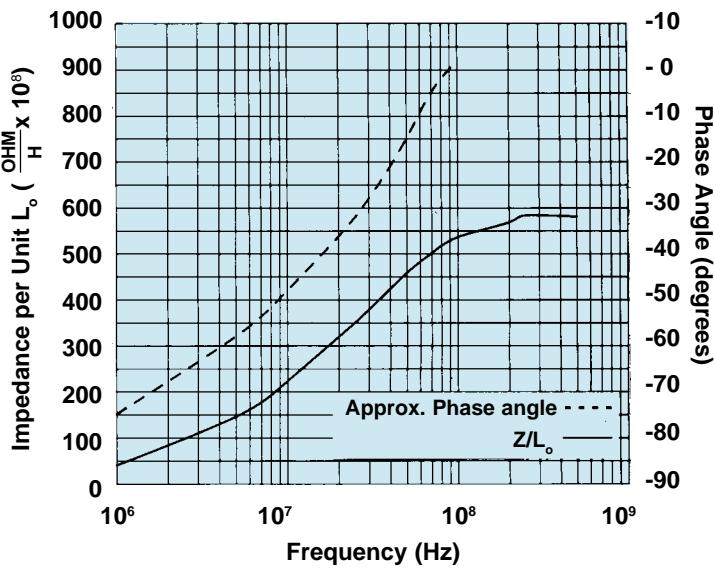


Figure 14 Nominal Impedance Per Unit L_o and Average Phase Angle vs. Frequency for Fair-Rite 43 material using HP 4191A.

Figures 13, 14, and 15 are graphs of the average impedance per unit L_o , and phase angle (Φ) for 73, 43, and 61 material respectively. To determine the impedance of a core using these graphs, the designer needs to know the physical dimensions of the core, the frequency of concern, and the material.

As an example:

A designer utilizing a ferrite core wants to guarantee maximum impedance for the frequency range of 25 MHz to 150 MHz. 43 material is chosen. The core must accept a #22 awg wire, and fit in a space of 10 mm by 5 mm. The inside diameter will be specified as .8 mm.

Using the graph of Figure 14, Z/Lo at 25 MHz for 43 material is 350×10^8 ohm/H. Solving for the estimated impedance by first using 10 mm for the outside diameter of the bead and 5 mm for the length...

$$Z = 350 \times 10^8 \times 0.046 \times \log_{10}(10/.8) \times 5 \times 10^{-8} = 88.3 \text{ ohm}$$

then using 5 mm for the outside diameter and 10 mm for the length

$$Z = 350 \times 10^8 \times 0.046 \times \log_{10}(5/.8) \times 10 \times 10^{-8} = 128.1 \text{ ohm}$$

In this instance, as in most, maximum impedance is achieved by using the smaller OD with the longer length. If the ID was larger, for instance 4 mm, the reverse would have been true. The same approach may be used for different materials, dimensions, and frequencies.

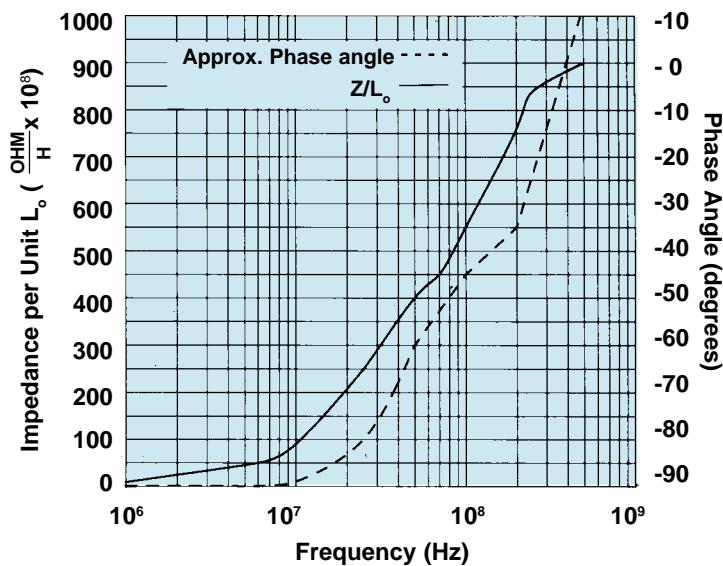


Figure 15 Nominal Impedance Per Unit L_o and Average Phase Angle vs. Frequency for Fair-Rite 61 material using HP 4191A.

Technical Information

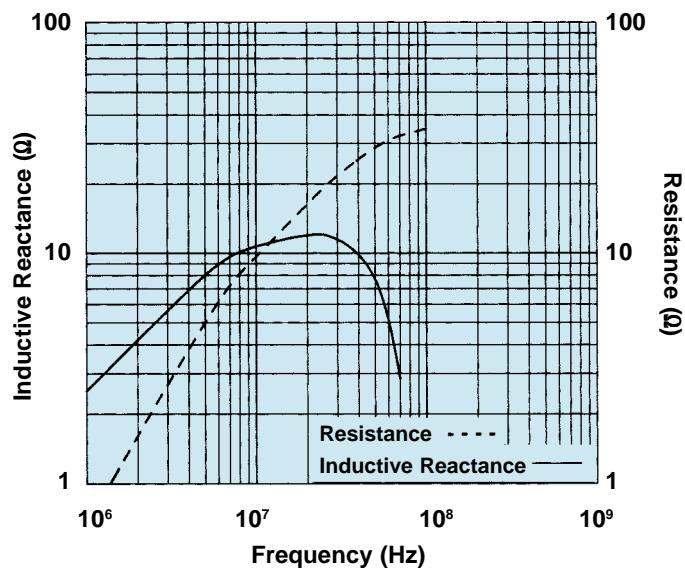


Figure 16 Graph of Inductive Reactance, (ωL_s), and Series Resistance, (R_s) for Fair-Rite PN 2643000101.

The previous discussion does assume that the core of choice is cylindrical. If the ferrite core being used is for flat ribbon, or bundled cable, or a multi-hole plate, the calculation for the L_o becomes more difficult, and fairly accurate figures for the cores path length and effective area must be obtained in order to calculate the air core inductance. In all cases though, the increase in impedance will be directly proportional to the height/length as long as the increase in height/length does not cause the core to be in resonance.

The phase angle plotted for each of the three materials is an average. The inductive reactance, and the series resistance can be calculated using these graphs and equations 7 and 8. Figure 16 is just such a graph for a Fair-Rite bead in 43 material.

The Environment

Ferrite's magnetic parameters can be affected by temperature, and field strength. Figures 17 and 18 are graphs of impedance vs. temperature for a Fair-Rite core in 73, 43, and 61 material at 25 and 100 MHz. The most temperature stable of these materials is 61, with a decrease in impedance of 8% at 100°C and 100 MHz as compared with over 25% for 43 at the same frequency and temperature. These curves may be used to adjust the specified room temperature impedance if desired attenuation is to be at elevated temperatures.

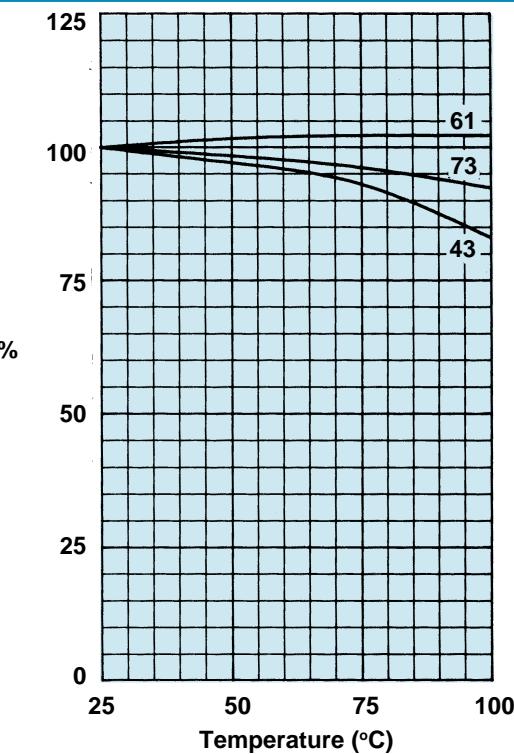


Figure 17 Percent of Original Impedance vs. Temperature at a frequency of 25 MHz for Fair-Rite's three major suppressor materials. Measured on 26-000801 using HP 4193A.

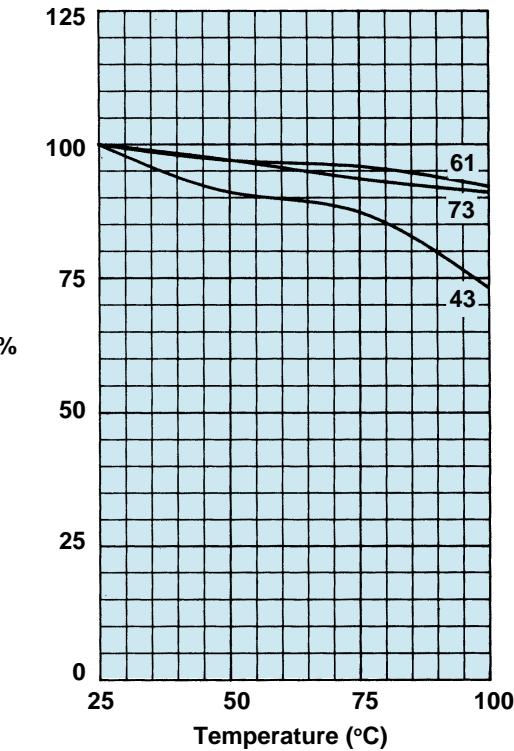


Figure 18 Percent of Original Impedance vs. Temperature at a frequency of 100 MHz for Fair-Rite's three major suppressor materials. Measured on 26-000801 using HP 4193A.

Technical Information

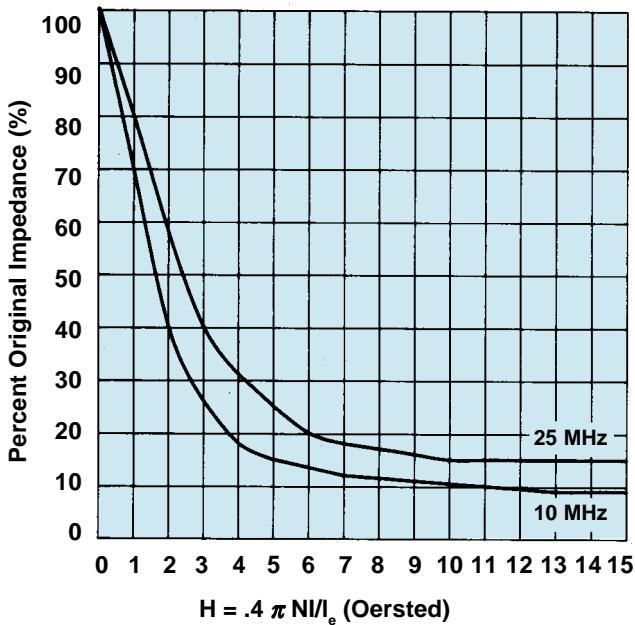


Figure 19 Impedance vs. Field Strength, H, in oersted, for 73 material, for two frequencies. Measurements made using HP 4193A.

Biases

As in the case of temperature, dc and 50 or 60 Hz power current will also affect the same intrinsic ferrite characteristics which in turn will result in lowering of the impedance of the suppressor core.

Figure 20 illustrates the effect of dc bias on the initial impedance of 43 material. The curves depict the degradation in impedance vs. field strength, H in oersted, for frequencies of 25, 50 and 100 MHz.

In the design example cited earlier, the user chose a 43 material ferrite core with a 5 mm outside diameter, .8 mm inside diameter and a 10 mm length. Suppose this core will be exposed to 1 amp dc, and the resulting impedance must be determined.

In order to calculate the field strength, H, the path length of the core must be established. This is a lengthy procedure that involves first calculating the core constants, C_1 and C_2 , then using these to find the path length.

These calculations reduce to:

$$\text{path length } le = 2\pi [\log_e(r_2/r_1)]/(1/r_1 - 1/r_2) = .55 \text{ cm eq.[10]}$$

$$\text{and } H = .4 \pi NI/le = 2.28 \text{ oersted eq.[11]}$$

$$\text{where: } r_1 = \frac{ID}{2} \quad r_2 = \frac{OD}{2}$$

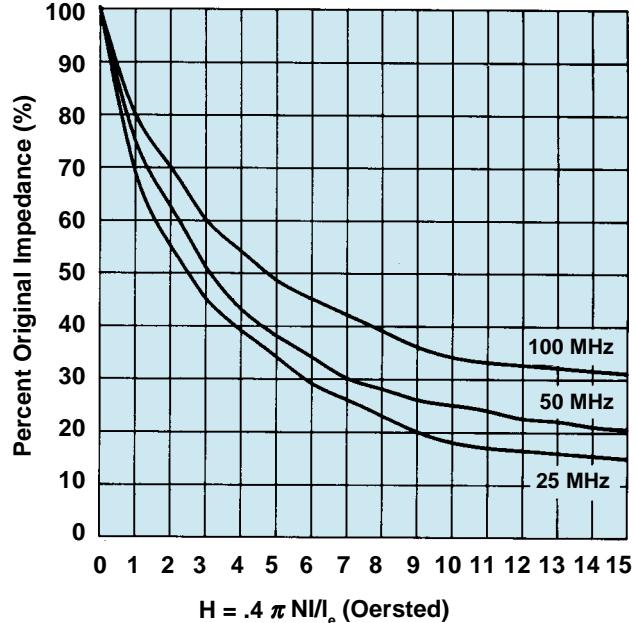


Figure 20 Impedance vs. Field Strength, H, in oersted, for 43 material for three frequencies. Measurements made using HP 4193A.

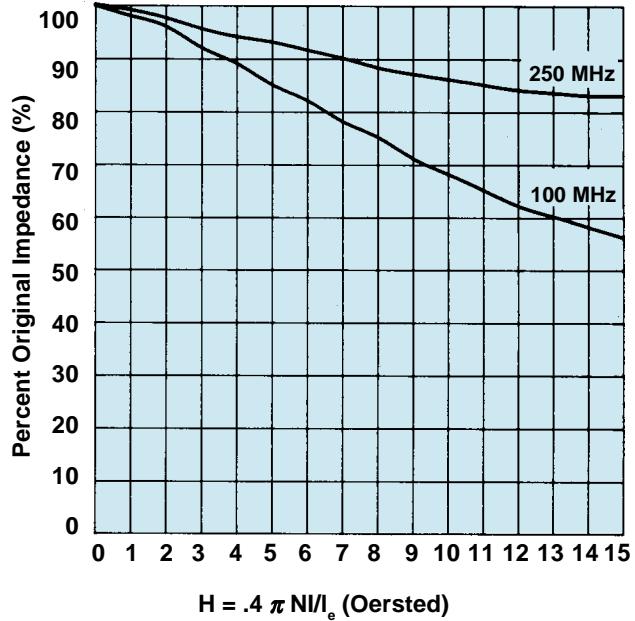


Figure 21 Impedance vs. Field Strength, H, in oersted, for 61 material, for two frequencies. Measurements made using HP 4193A (100 MHz) and HP 4191A (250 MHz).

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The curves confirm that the greatest degradation in impedance occurs at the lower frequency, 25 MHz, and for 2.28 oersted the resulting impedance will be approximately 52% of the original, in this case, 66.6 ohm (.52 x 128.1 ohm).

Similar plots are made for 73 material in Figure 19, and 61 material in Figure 21. Two frequencies are plotted for 73 material, 10 and 25 MHz, and two for 61 material, 100 and 250 MHz.

Resistivity

The dc resistivities of ferrites can range from 10 ohm-cm to more than 10^9 ohm-cm. Generally, high permeability manganese zinc ferrites have low resistivities, below 10^2 ohm-cm, while nickel zinc ferrites have resistivities that range from 10^5 - 10^{12} ohm-cm. In most instances this parameter is measured using low voltage values, and since a ferrite's resistivity is voltage sensitive, these values may not be valid if the body of the core itself is exposed to high dc or ac values. There are ferrite materials available that have resistivity of 10^9 ohm-cm measured with 1000 volts. Fair-Rite products offers 44 material for such applications. If the frequency that must be attenuated is lower than 25 MHz, requiring a manganese zinc ferrite, coating the core with Parylene, epoxy or polyurethane varnish or using insulated wires, may be the only solution.

Helpful Hints.....

Increasing Impedance

Impedance can be increased significantly by adding turns to a bead or a coil on a slug. Figure 22 is a graph of impedance vs. frequency for a large toroidal core with one, two and four turns. The impedance will increase in direct proportion to the turns squared, but the frequency at which the maximum impedance is reached is lowered due to the additional capacitive effects.

Figure 23 is a graph of different plots of impedance for the same size slug, same number of turns, in different materials. The impedances gained by this type of configuration can be significant. Again there is a tradeoff; increasing the permeability lowers the resonant frequency at which the impedance becomes maximum, therefore narrowing the effective frequency band. The lower the initial permeability of a material, the higher the frequency where this occurs.

Increasing DC Handling

Introducing an airgap in the cores path length can decrease the degrading effects of dc bias. The larger the gap the less effect the bias will have on the impedance. Gaps vary from finishing gaps in mated parts to the gaps found in open magnetic circuits, for example, a slug. Figure 24 shows the effect of dc bias on a flat ribbon cable core with different currents and several size airgaps. Note that the higher the frequency the less the effect of the gap and the current.

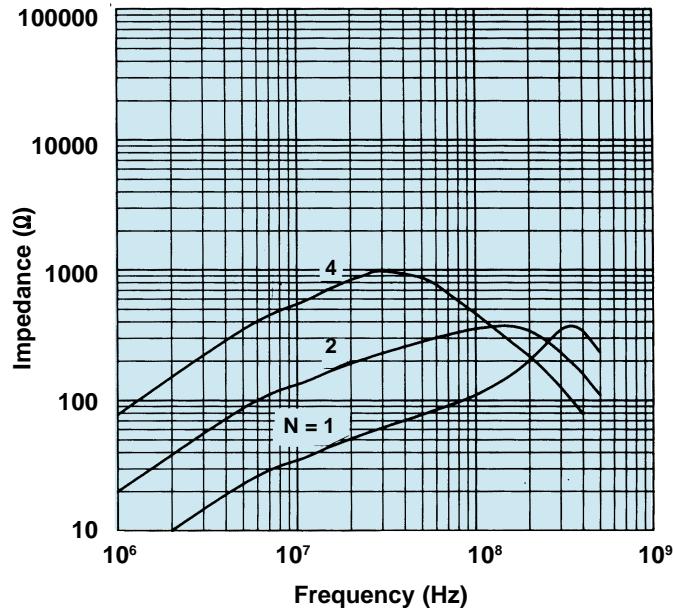


Figure 22 Impedance vs. Frequency for Fair-Rite large bead, PN 2643803802, with one, two and four turns.

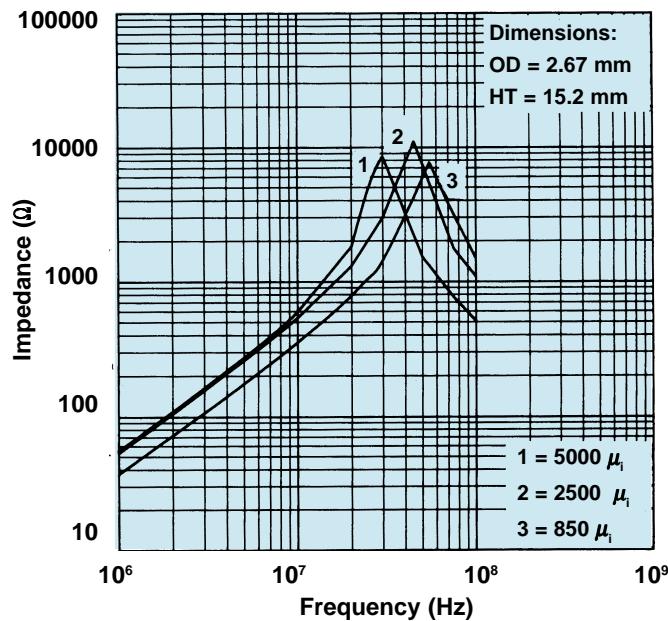


Figure 23 Impedance vs. Frequency for slug type core in a coil varying material.

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Specifying the Core

Most ferrite manufacturers specify their EMI product line in terms of impedance at select frequencies.

Fair-Rite Products specifies impedances at two frequencies for each material. The impedance of the cores are controlled to meet a minimum at the lower frequency and at the higher frequency is tolerated at $\pm 20\%$. The measuring equipment is a HP 4193A, unless the frequency is above 100 MHz. at which time a HP 4191-A is used. Impedance values measured on other equipment, even if it is Hewlett-Packard, may not correlate.

Figure 25 shows the equivalent circuit of an interference source with an internal impedance of Z_s , generating an interference signal through the series impedance of the suppressor core Z_{sc} into the load impedance Z_L .

Most manufacturers are specifying cores for EMI applications in terms of impedance, but often the end user needs to know the attenuation. The relationship that exists between these two parameters is:

$$\text{Attenuation} = 20 \log_{10} Z_s + Z_{sc} + Z_L / Z_s + Z_L \text{ dB eq.[12]}$$

where: Z_s = source impedance

Z_{sc} = suppressor core impedance

Z_L = load impedance

This relationship is dependent on the impedance of the source generating the noise and the impedance of the load receiving it. These values are usually complex numbers that can be infinite in scope and not easily obtained by the designer therefore it is recommended that the attenuation calculations be verified in the actual circuit by appropriate measurements.

Selecting a value of one ohm for both the load and the source impedance, as may be the case when the source is a switch mode power supply and the load many low impedance circuits, simplifies the equation and allows comparison of ferrite cores in term of attenuation.

Under these conditions, the equation reduces to:

$$A = 20 \log_{10} |Z_{sc}|/2 \text{ dB eq.[13]}$$

$Z_{sc} \gg 1 \text{ ohm}$

Some Examples

In the circuit shown in Figure 26a, a metal enclosure is used to eliminate radiated interference generated by the commutation of the dc motor. This enclosure, however, will not prevent the conduction of noise on the power cables of the dc motor. This conducted noise in turn might affect other circuits with either conducted or radiated interference.

When a metal enclosure is used in conjunction with ferrite suppression cores and feed-through capacitors, as shown in Figure 26b, the conducted noise is eliminated from the circuit. (1)

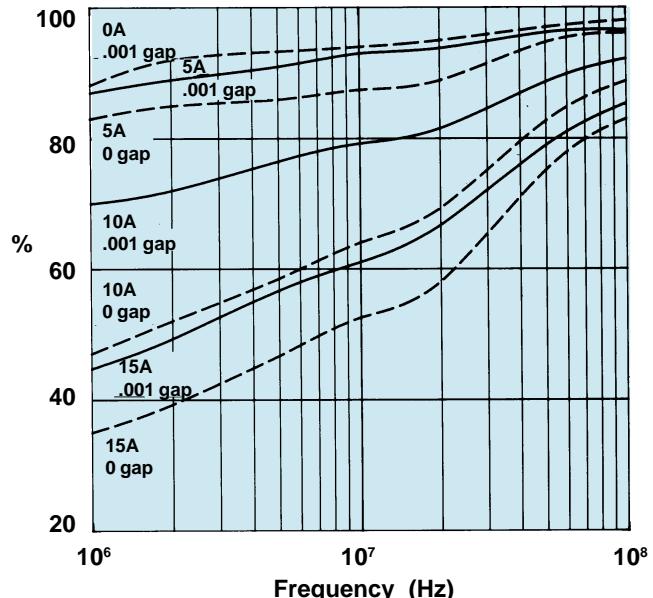


Figure 24 Percent of Original Zero Gap, Zero Bias Impedance vs. Frequency, dc bias and gap for 43 material flat cable suppression core 2643166851.

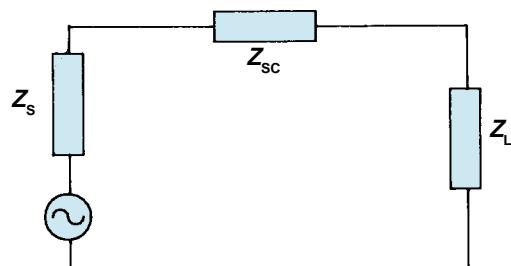


Figure 25 Equivalent Circuit

Technical Information

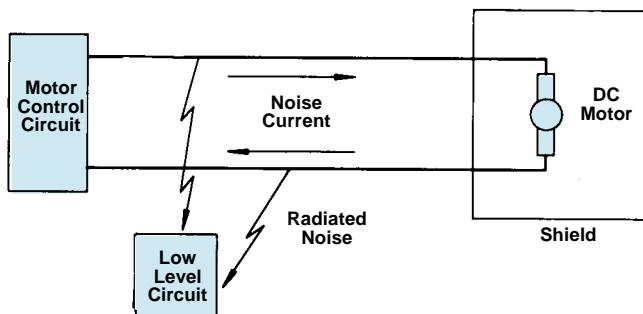


Figure 26a Commutation noise is interfering with low-level circuits.

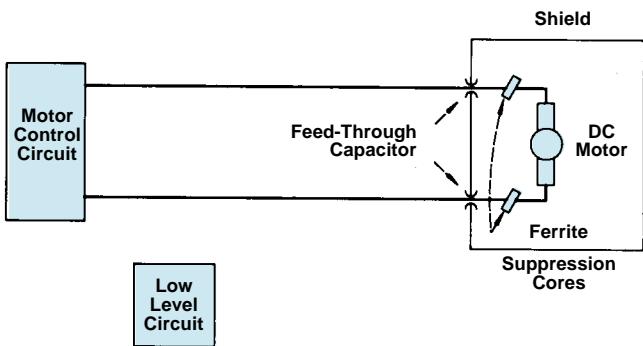


Figure 26b Ferrite suppression cores used in conjunction with feed-through capacitors to eliminate interference.

In applications that must accommodate dc, ferrite materials are influenced by the level of dc magnetization. This might require the use of a suppressor core with an airgap in its magnetic circuit.

In Figure 27a, a ferrite core is used to suppress common-mode noise, effectively reducing ground-loop coupling without affecting the circuit load current. Figure 27b illustrates the use of a ferrite core to suppress conducted noise, without introducing significant circuit losses at low frequencies.(2)

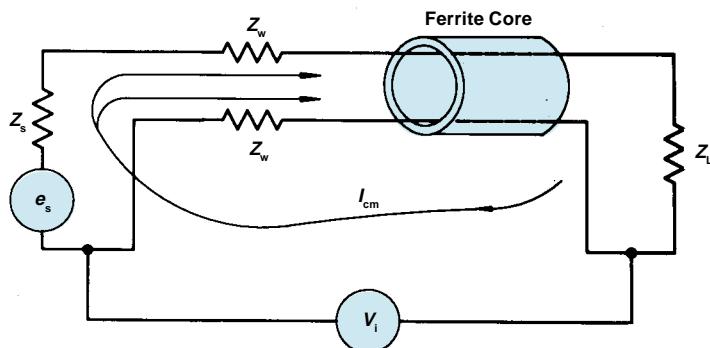


Figure 27a Ferrite core used for suppressing common-mode noise.

$$\begin{aligned} I_{cm} &= \text{Common-mode current} \\ Z_w &= \text{Impedance of wire} \end{aligned}$$

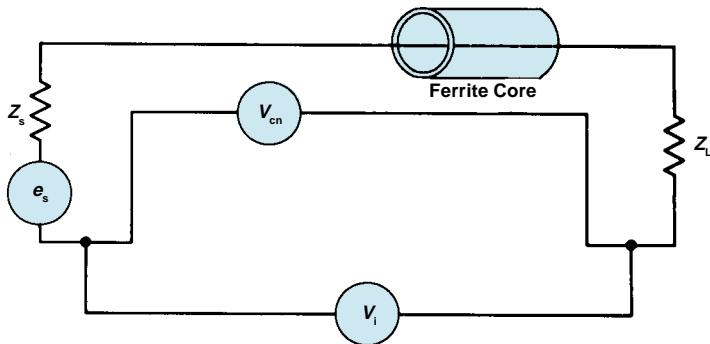


Figure 27b Ferrite core used to suppress conducted noise.

$$\begin{aligned} Z_L &= \text{Load Impedance} \\ V_i &= \text{Common-mode voltage} \\ V_{cn} &= \text{Conducted noise voltage} \end{aligned}$$

(1) Ott, Henry W, *NOISE REDUCTION TECHNIQUES IN ELECTRONIC SYSTEMS*. Second Edition John Wiley & Sons. New York, 1988.

(2) Violette, J.L. Norman, White, Donald, R.J., and Violette, Michael F., *ELECTROMAGNETIC COMPATIBILITY HANDBOOK*, Van Nostrand Reinhold Company Inc, New York, 1987.

Typical Performance Data

Beads on Leads, page 85

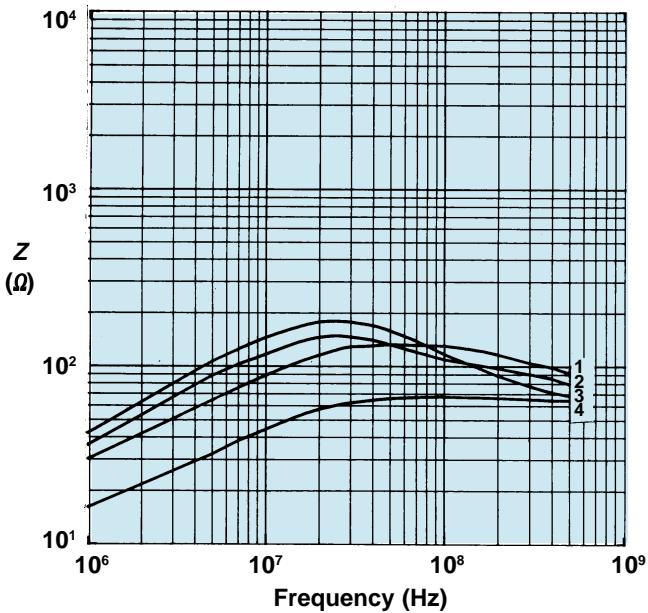


Figure 28 Impedance vs. Frequency for 73 material beads on leads.

- | | |
|--------------|--------------|
| 1 2773002112 | 3 2773008112 |
| 2 2773007112 | 4 2773001112 |

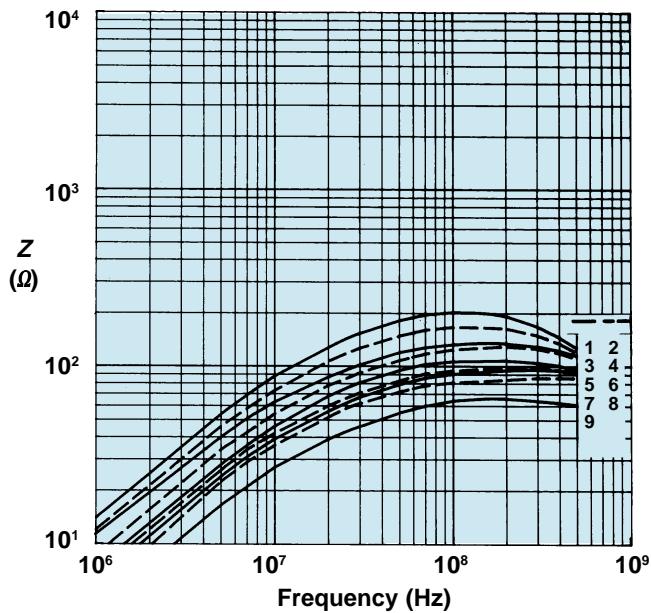


Figure 29 Impedance vs. Frequency for 43 material beads on leads.

- | | | |
|--------------|--------------|--------------|
| 1 2743009112 | 4 2743002112 | 7 2743005112 |
| 2 2743008112 | 5 2743004112 | 8 2743015112 |
| 3 2743007112 | 6 2743003112 | 9 2743001112 |

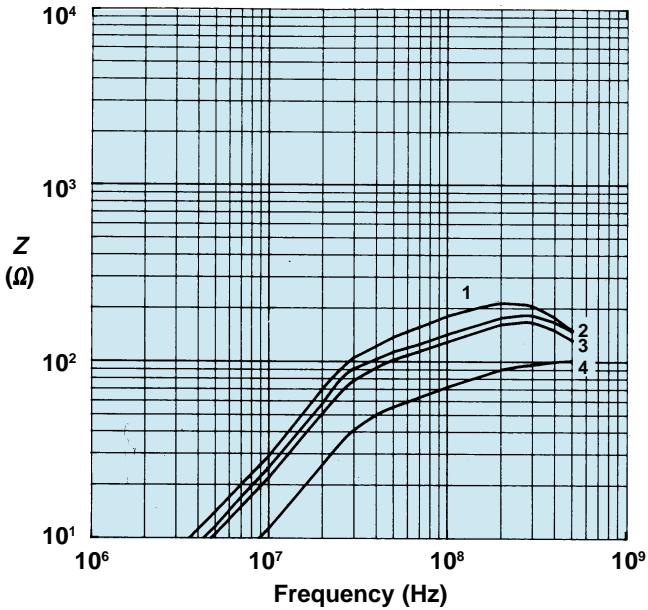


Figure 30 Impedance vs. Frequency for 61 material beads on leads.

- | | |
|--------------|--------------|
| 1 2761008112 | 3 2761002112 |
| 2 2761007112 | 4 2761001112 |

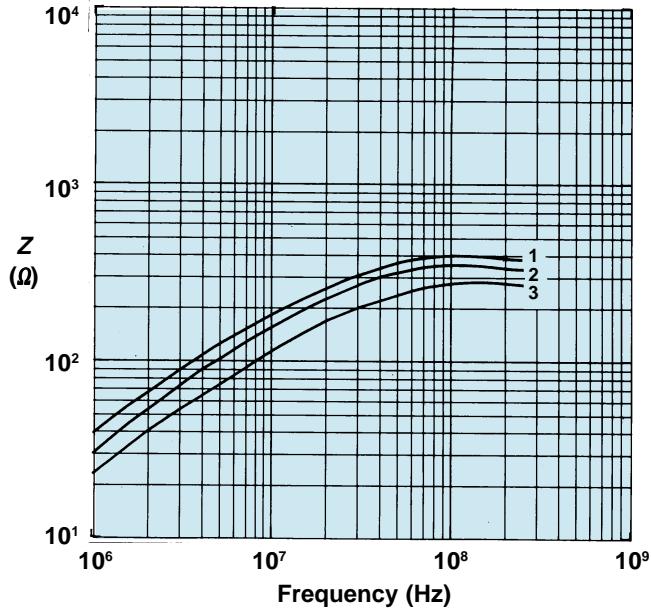


Figure 31 Impedance vs. Frequency for large diameter 43 material beads on leads.

- | | | |
|--------------|--------------|--------------|
| 1 2743014221 | 2 2743013211 | 3 2743012201 |
|--------------|--------------|--------------|

Typical Performance Data

Shield Beads, pages 64 - 67

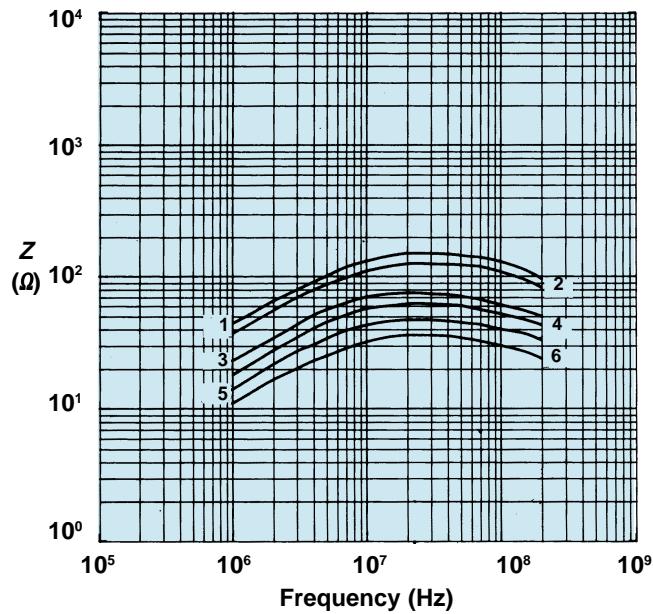


Figure 32 Impedance vs. Frequency for 73 material shield beads.

1 2673021801	3 2673000801	5 2673002201
2 2673000701	4 2673000301	6 2673001001

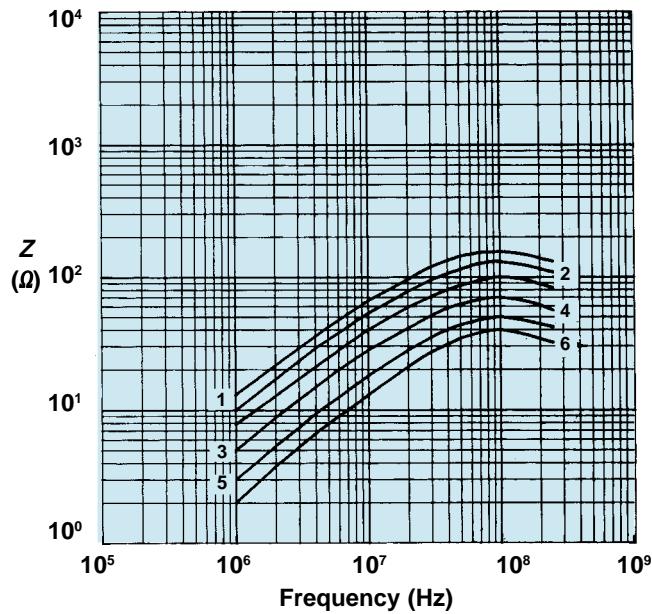


Figure 33 Impedance vs. Frequency for 43 material shield beads.

1 2643021801	3 2643000801	5 2643001001
2 2643000701	4 2643000301	6 2643001501

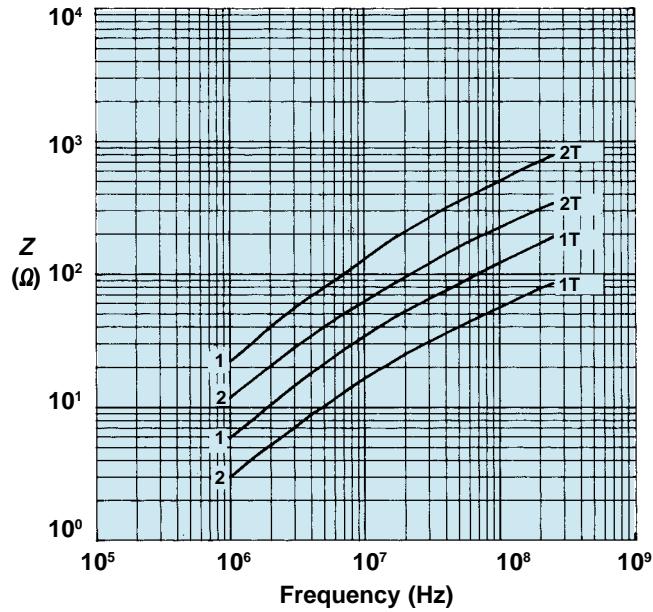


Figure 34 Impedance vs. Frequency for larger shield beads wound with one and two turns.

1 2643803802	2 2643801002
--------------	--------------

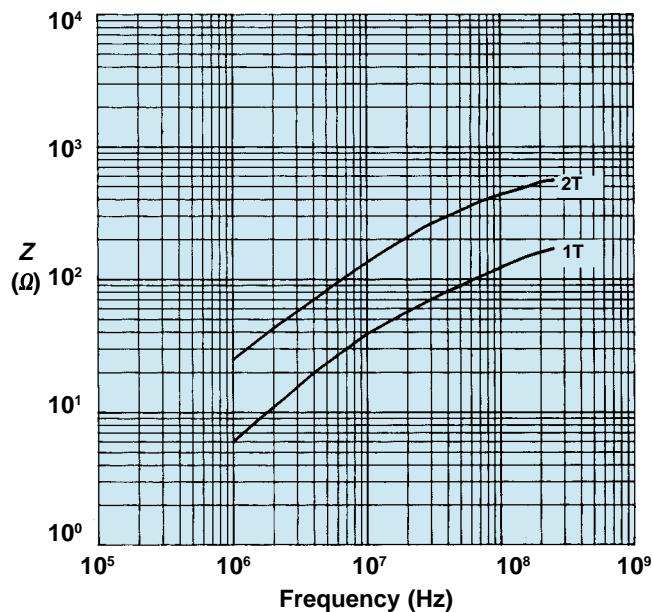


Figure 35 Impedance vs. Frequency for larger shield bead 2643804502 wound with one and two turns.

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Typical Performance Data

Shield Beads, pages 64 - 67

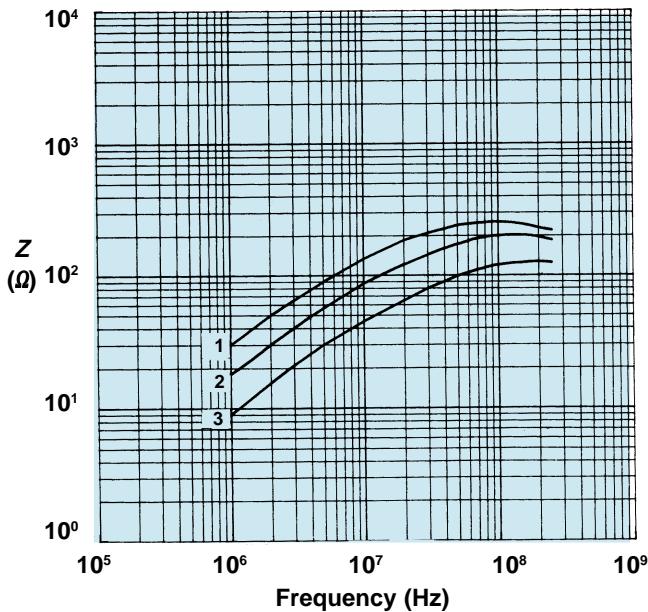


Figure 36 Impedance vs. Frequency for larger shield beads with the same OD and ID but different lengths.

1 2643625202 2 2643625102 3 2643625002

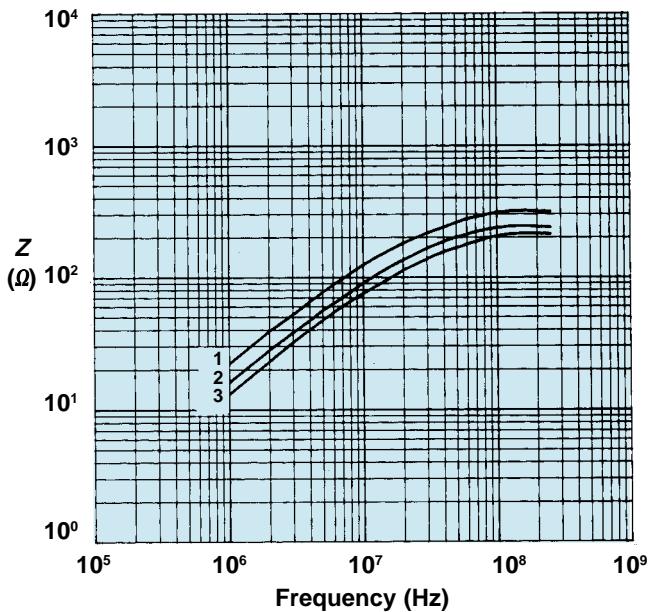


Figure 37 Impedance vs. Frequency for larger shield beads with the same OD and ID but different lengths.

1 2643626202 2 2643625902 3 2643626102

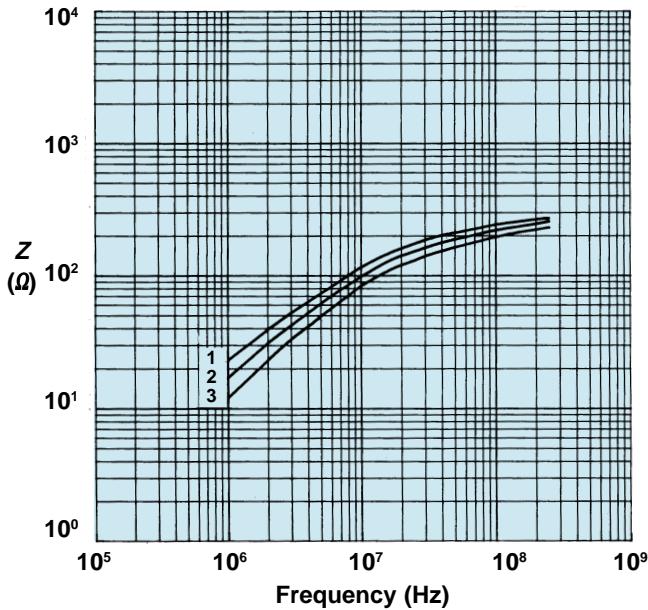
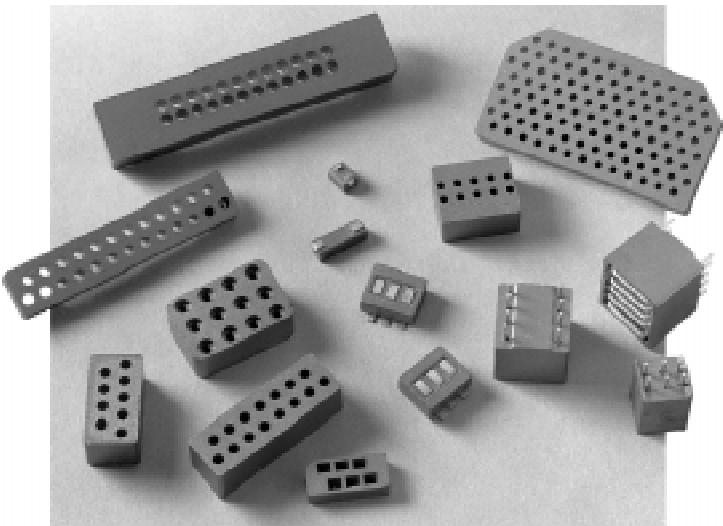


Figure 38 Impedance vs. Frequency for larger shield beads with Impedances at 100 MHz of 200 Ω or more.

1 2643540002 2 2643102002 3 2643665702



Typical Performance Data

SM Beads, pages 80 - 83

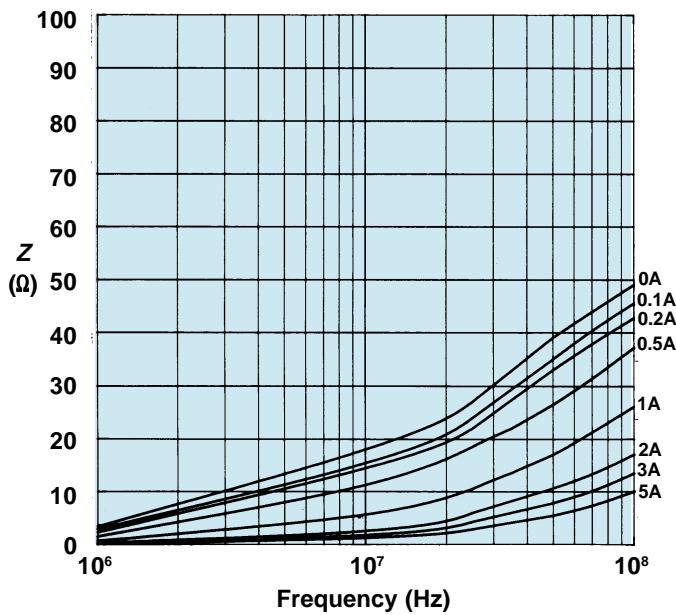


Figure 39 Impedance vs. Frequency with dc bias as parameter for the SM Bead 2743019447.

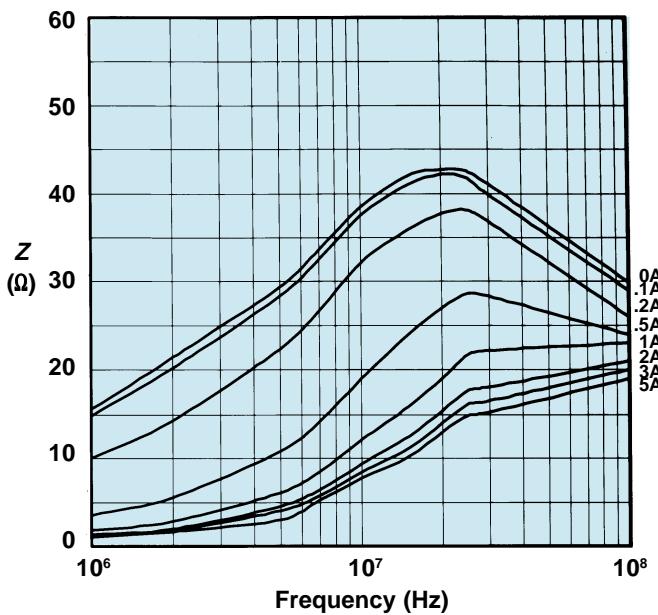


Figure 40 Impedance vs. Frequency with dc bias as parameter for the SM Bead 2773019447.

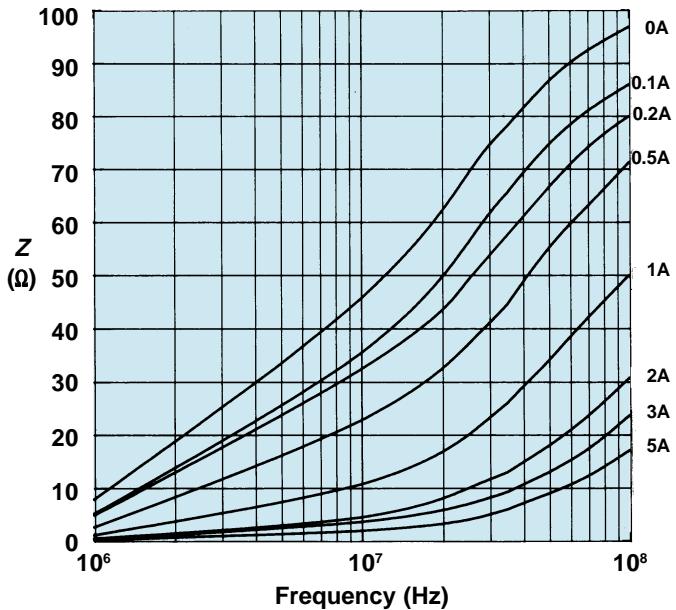


Figure 41 Impedance vs. Frequency with dc bias as parameter for the SM Bead 2743021447.

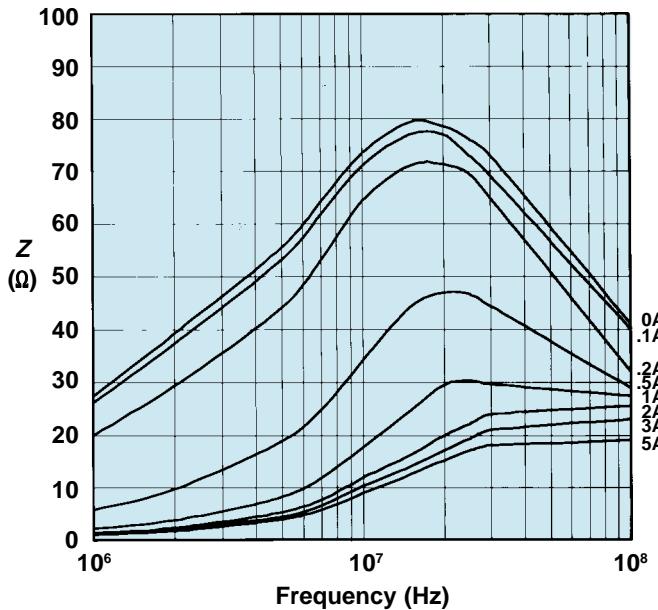


Figure 42 Impedance vs. Frequency with dc bias as parameter for the SM Bead 2773021447.

Typical Performance Data

SM Beads, pages 80 - 83

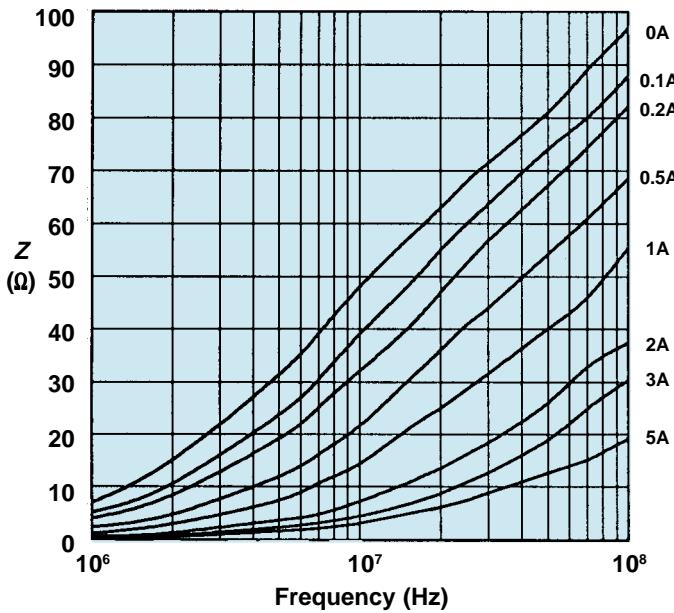


Figure 43 Impedance vs. Frequency with dc bias as parameter for the SM Bead 2743037447.

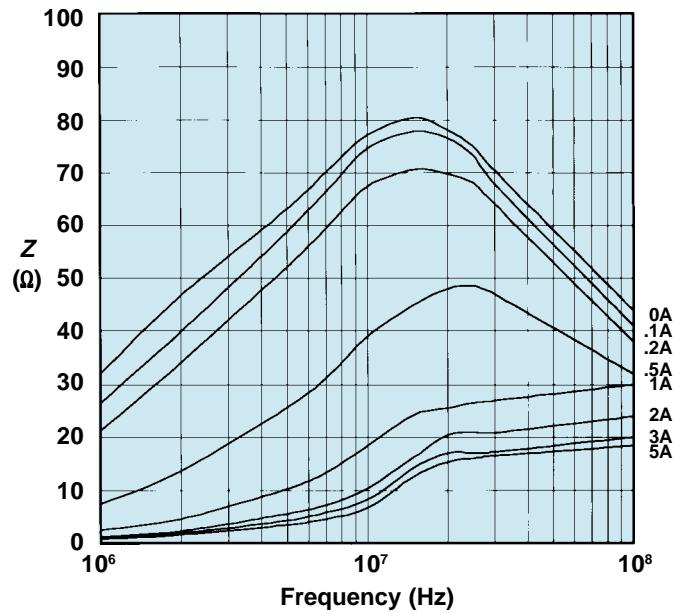


Figure 44 Impedance vs. Frequency with dc bias as parameter for the SM Bead 2773037447.

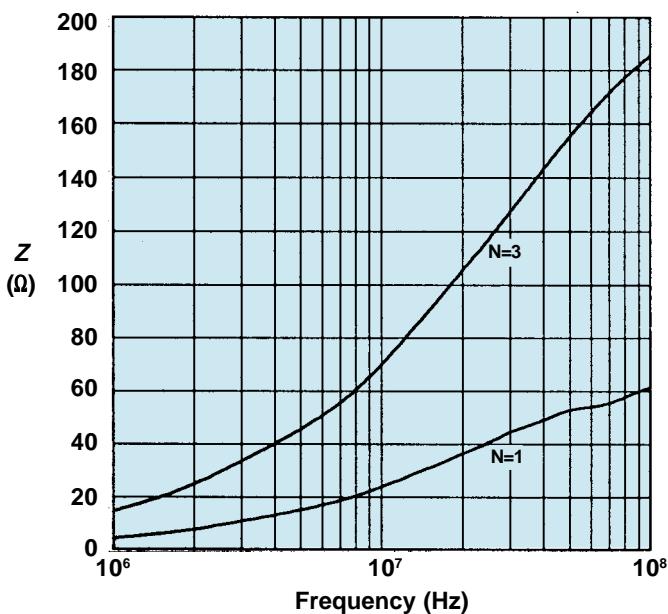


Figure 45 Impedance vs. Frequency for the SM Bead 2744040446 with one and three turns.

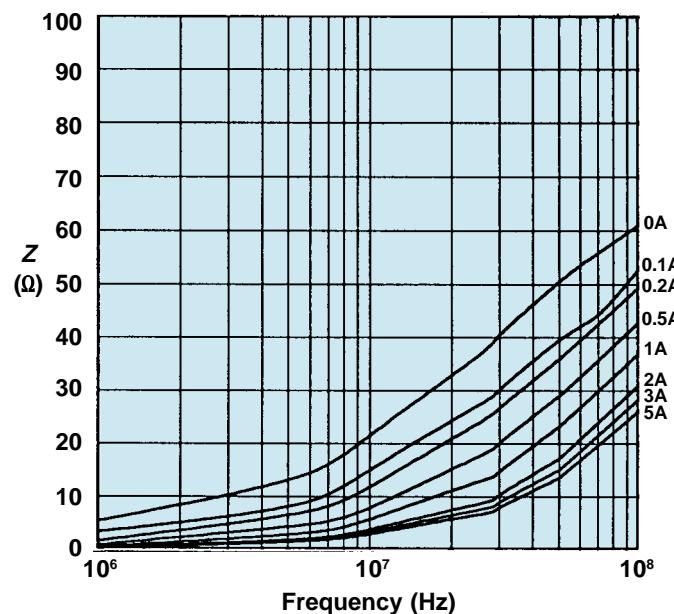


Figure 46 Impedance vs. Frequency with dc bias as parameter for the SM Bead 2744040446.

Typical Performance Data

Wound Beads, page 88

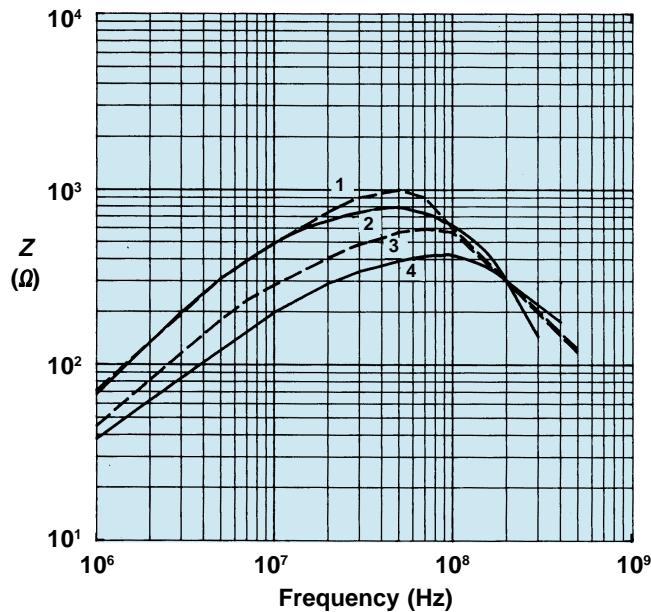


Figure 47 Impedance vs. Frequency for wound six hole beads in 44 material.

- | | |
|--------------|--------------|
| 1 2944666631 | 3 2944666651 |
| 2 2944666671 | 4 2944666661 |

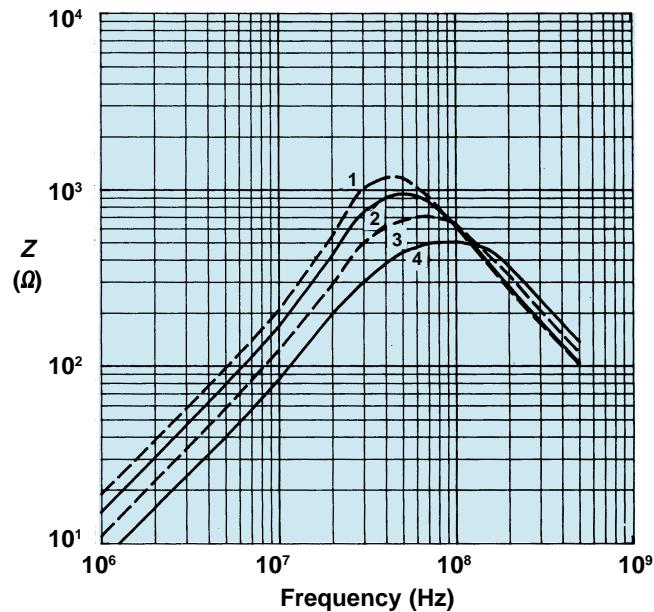


Figure 48 Impedance vs. Frequency for wound six hole beads in 61 material.

- | | |
|--------------|--------------|
| 1 2961666631 | 3 2961666651 |
| 2 2961666671 | 4 2961666661 |

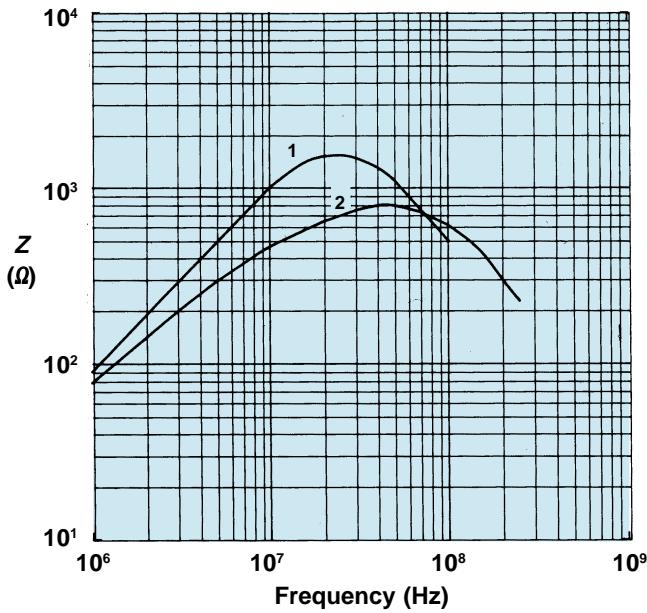
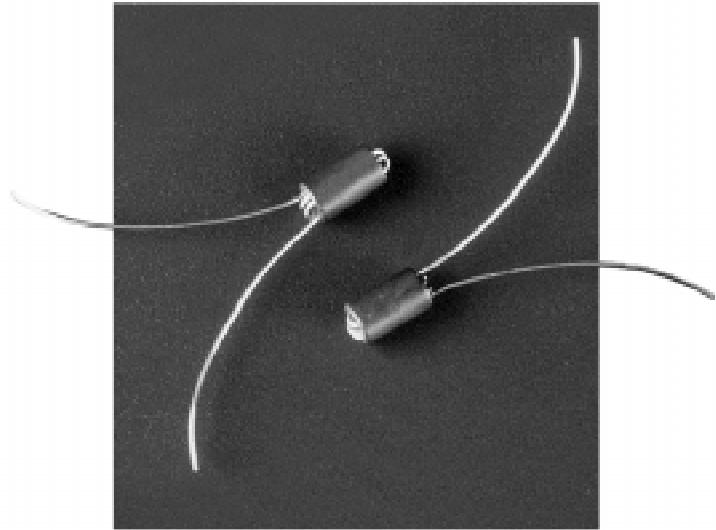


Figure 49 Impedance vs. Frequency for wound eleven hole beads in 44 material.

- | | |
|--------------|--------------------|
| 1 2944777741 | 2 2944777721 (2½T) |
|--------------|--------------------|



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Typical Performance Data

PC Beads, page 87

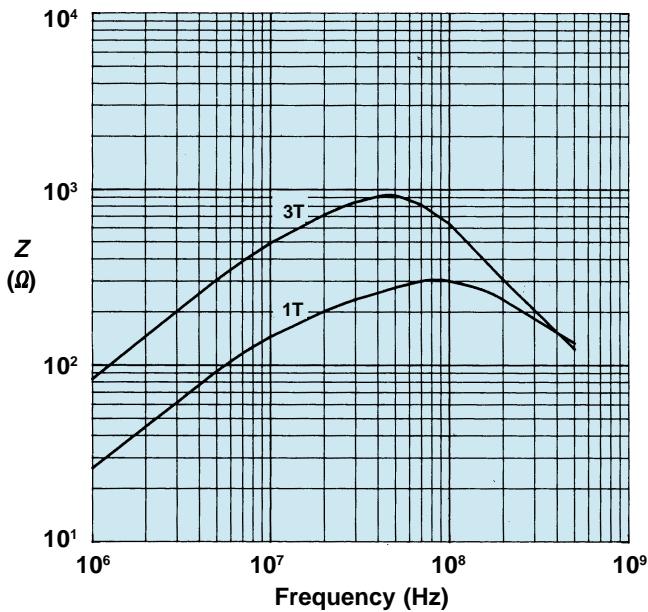


Figure 50 Impedance vs. Frequency for PC Bead 2944776101 for one and three turns.

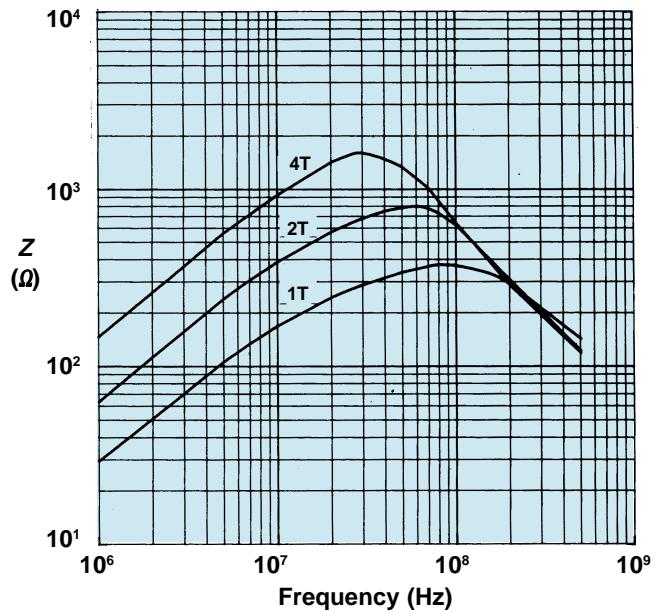


Figure 51 Impedance vs. Frequency for PC Bead 2944778301 for one, two and four turns.

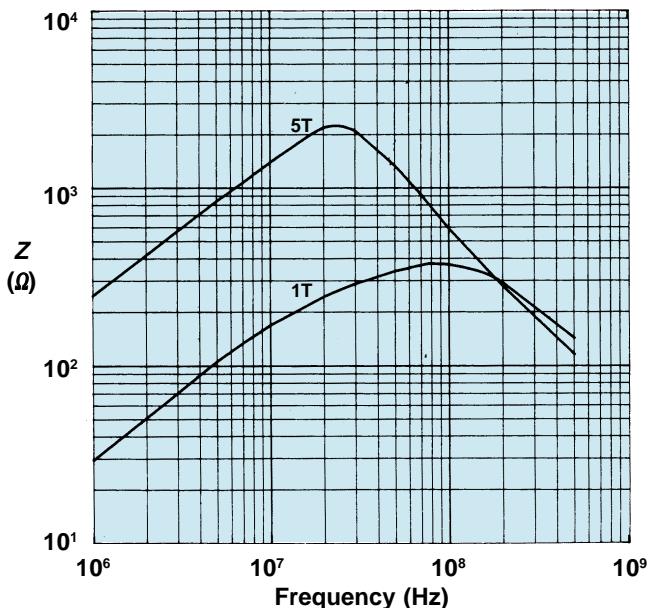
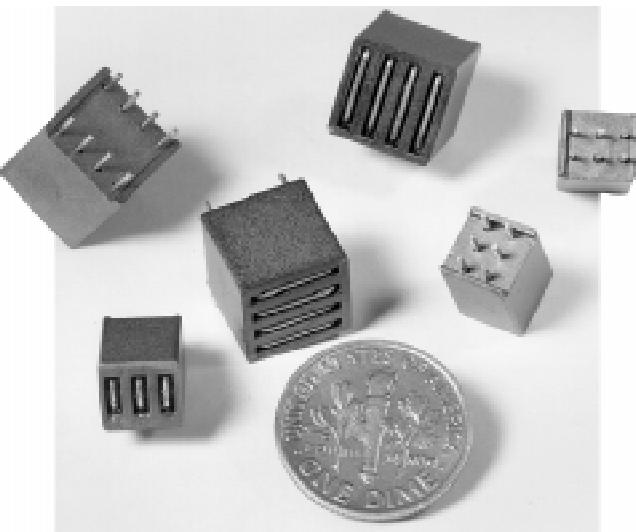


Figure 52 Impedance vs. Frequency for PC Bead 2944770301 for one and five turns.



Typical Performance Data

Cable Suppression Cores, pages 68 - 77

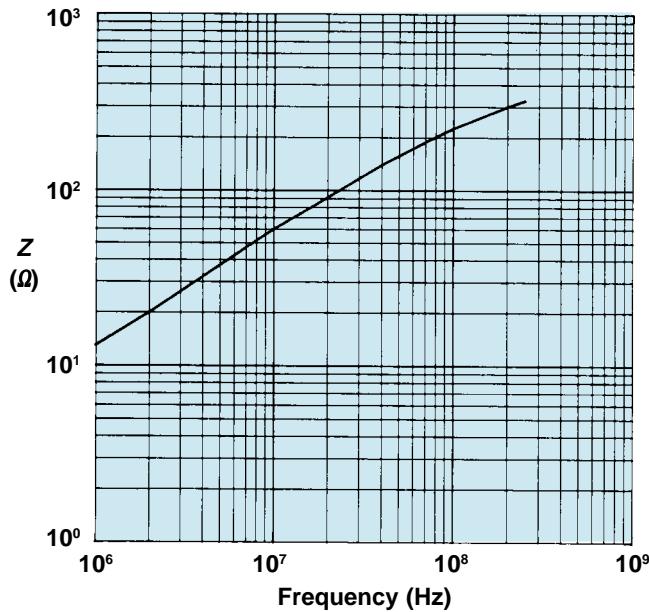


Figure 53 Impedance vs. Frequency for the one-piece flat cable suppression core 2643163851.

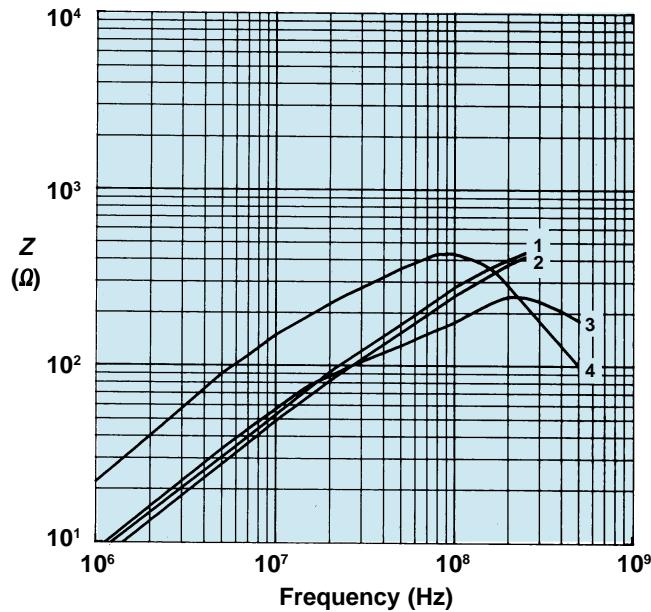


Figure 54 Impedance vs. Frequency for split flat cable suppression cores.

- | | |
|--------------|--------------|
| 1 2643163951 | 3 2643166451 |
| 2 2643164051 | 4 2643167551 |

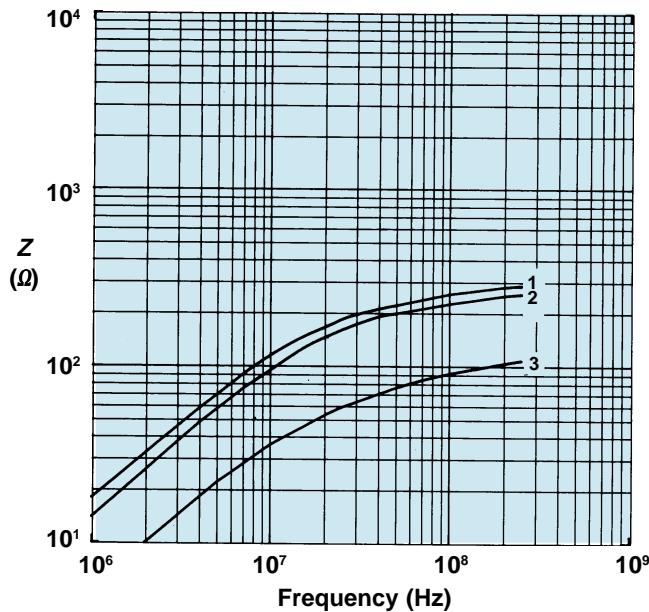


Figure 55 Impedance vs. Frequency for split round cable suppression cores.

- | | | |
|--------------|--------------|--------------|
| 1 2643164251 | 2 2643164151 | 3 2643166751 |
|--------------|--------------|--------------|

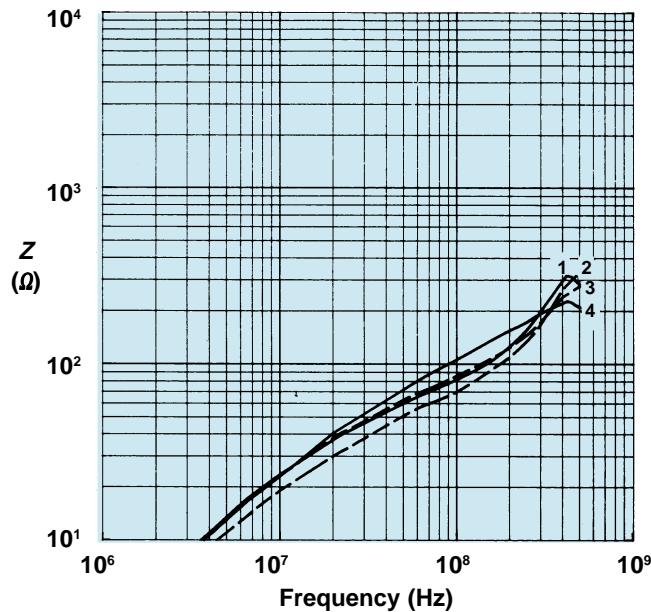


Figure 56 Impedance vs. Frequency for split round cable suppression cores.

- | | |
|--------------|--------------|
| 1 2643806406 | 3 2643665806 |
| 2 2643800506 | 4 2643625006 |

Typical Performance Data

Connector Suppression Plates, page 78

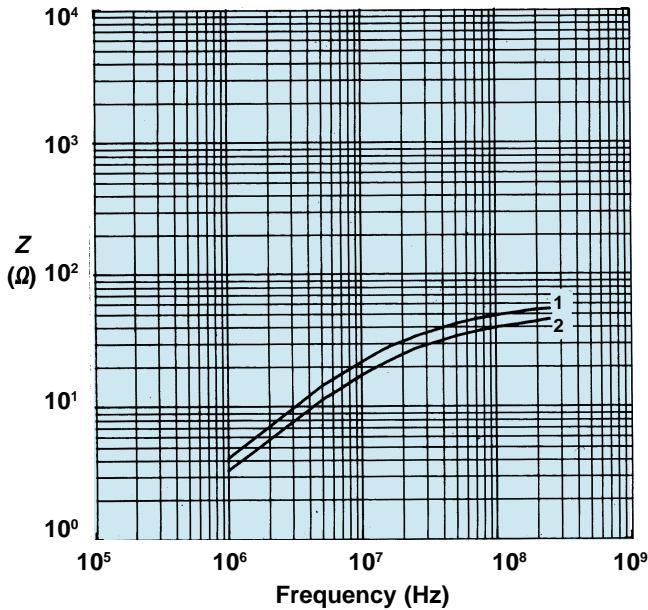


Figure 57 Impedance vs. Frequency for "D" type connector suppression plates, 2644236101, 2644236301 and 2644236001.

- 1 Inner Holes (7, 13 and 23 respectively)
- 2 Outer Holes (2)

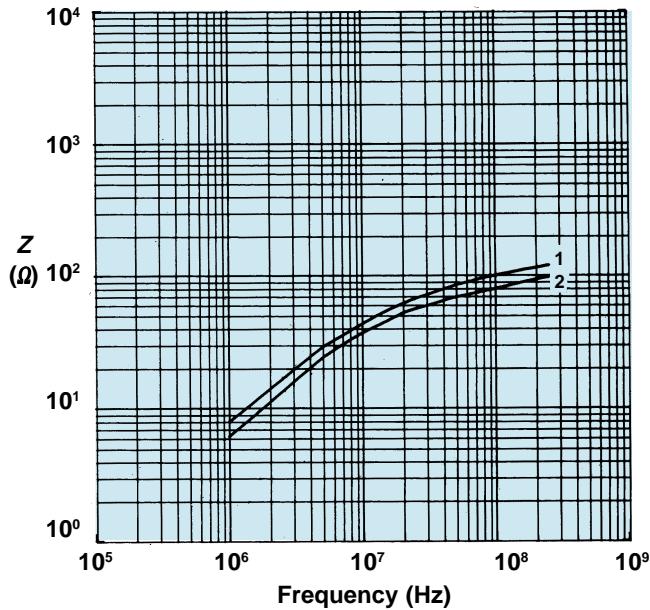


Figure 58 Impedance vs. Frequency for "D" type connector suppression plates, 2644236401, 2644236501 and 2644236601.

- 1 Inner Holes (7, 13 and 23 respectively)
- 2 Outer Holes (2)

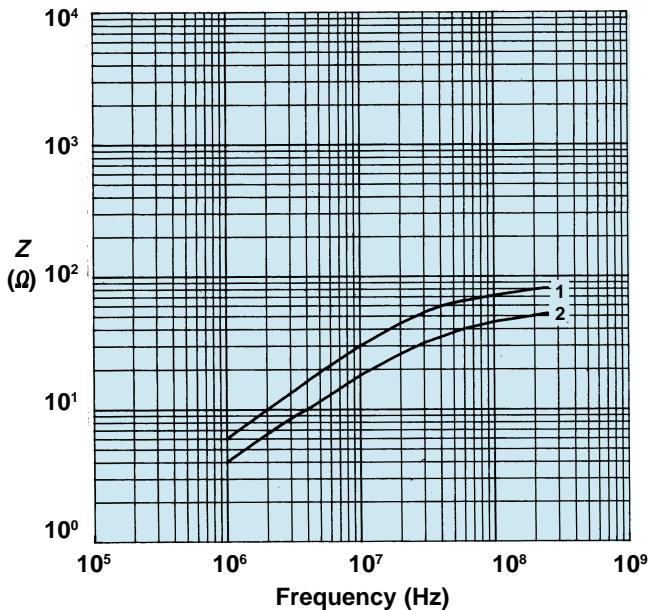


Figure 59 Impedance vs. Frequency for DIP/connector suppression plate 2644373841.

- 1 Inner Holes (12)
- 2 Outer Holes (4)

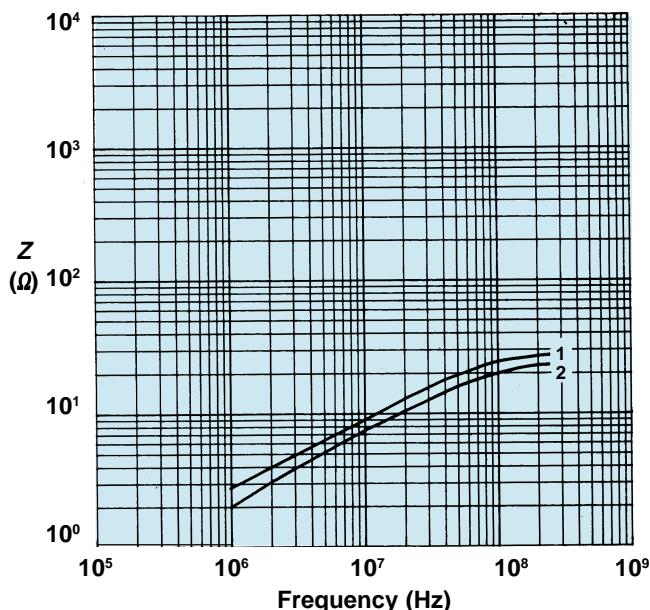


Figure 60 Impedance vs. Frequency for DIP/connector suppression plate 2644373941.

- 1 Inner Holes (12)
- 2 Outer Holes (4)

Ferrite Tile Absorber

for EMC Test Chamber Applications

Introduction

Fair-Rite's tile absorbers provide an attractive alternative to traditional large, foam-type absorber materials for new anechoic chambers or for upgrading older rooms for radiated emission and immunity measurements. While ferrite tiles are a relatively recent development, they have come into use wherever high absorption (-15 to -25 dB at <100 MHz) and compact size (6mm vs 2400mm for foam absorbers) are required. There are now hundreds of installations worldwide in compact and 3/10 meter FCC certified chambers. Ferrites themselves are inherently immune to fire, humidity and chemicals providing a reliable and compact solution for attenuating plane wave reflections in shielded enclosures.

Theory of Operation

The basic physics of operation for any planar electromagnetic absorber involves fundamental concepts as shown in Figure 1. When an electromagnetic wave traveling through free-space encounters a different medium (at Z=0), the wave will be reflected, transmitted, and/or absorbed. It is of course, the magnitude of the reflected signal which is usually of interest in this application. For ferrite tiles, the thickness is tuned so that the relative phases of the reflected and exiting wave cancel to form a resonant condition. This resonant condition appears as a deep "null" in the return loss response. This resonance is also a function of the frequency dependent electrical properties of the ferrite material such as relative permeability (μ_r) and permittivity (ϵ_r) which interact to determine the reflection coefficient (Γ), impedance (Z) and return loss (RL) according to the following formulas:

$$Z_f = \sqrt{\frac{\mu_r}{\epsilon_r}} \cdot \tanh \left[\left(\frac{j2\pi d}{\lambda} \right) \left(\sqrt{\mu_r \epsilon_r} \right) \right] \text{ (ohm)}$$

$$\Gamma = \frac{Z_f - Z_0}{Z_f + Z_0}$$

$$RL = 20 \log_{10} (\Gamma) \text{ (dB)}$$

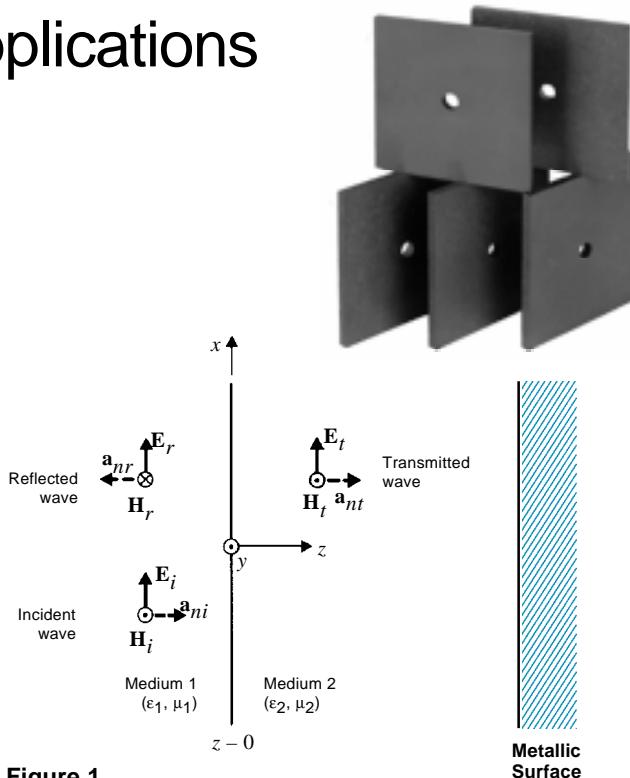


Figure 1

Where :

- μ_1 = relative permeability of medium 1 (air)
- ϵ_1 = relative permittivity of medium 1 (air)
- μ_2 = relative permeability of medium 2 (ferrite)
- ϵ_2 = relative permittivity of medium 2 (ferrite)
- Γ = reflection coefficient of metal backed ferrite tile
- Z_f = input impedance of metal backed ferrite tile
- Z_0 = impedance of free space (air)
- E_i, H_i = components of incident plane wave
- E_r, H_r = reflected components of incident plane wave
- E_t, H_t = transmitted components of incident plane wave
- d = thickness of medium 2 (ferrite)

Increasing Bandwidth

For some chamber applications increased absorber bandwidth may be desired to comply with high frequency testing needs. One technique shown in figure 2 increases the bandwidth of ferrite tile installations by mounting the tile over a dielectric spacer (typically wood) of appropriate thickness. When both tile and spacer thicknesses are optimized, the frequency response is shifted upward to improve return loss performance from 600-1500 MHz (see figure 3). Of course, if increased bandwidth up to 20 GHz is desired, several absorber vendors provide completely engineered hybrid absorbers using specially designed pyramidal and wedge shaped dielectric absorbers matched to ferrite tiles.

Ferrite Tile Absorber

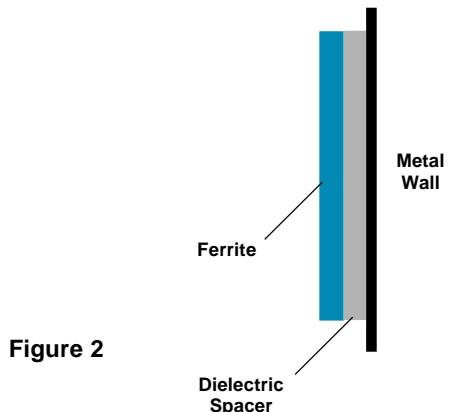


Figure 2

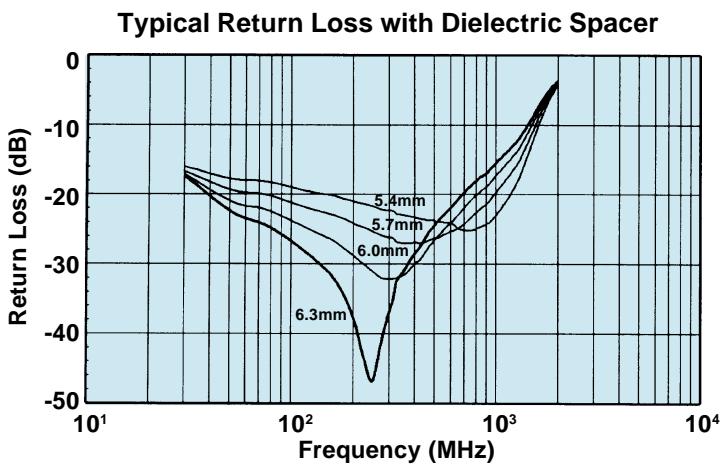


Figure 3

Return loss vs angle of incidence for TM polarization is shown in figure 4. Return loss curves for TE polarization (not shown) are similar.

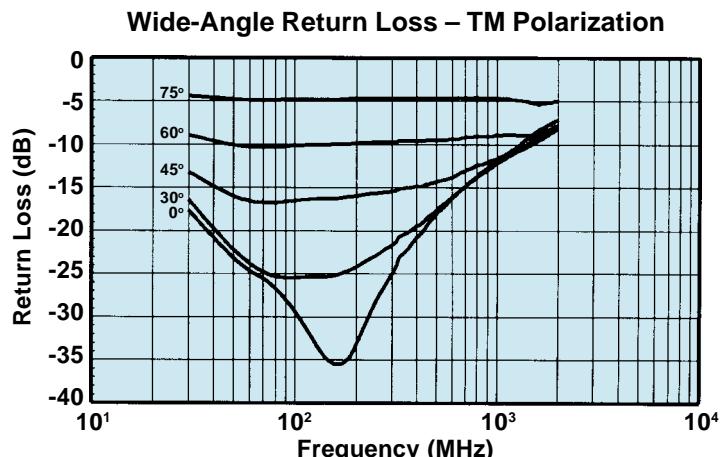


Figure 4

Precision Dimensions

Studies have shown that maximum low-frequency performance is obtained when tile to tile gaps are minimized. Fair-Rite precisely machines each of the six surfaces to $\pm 0.13\text{mm}$ (.005") to ensure a tight tile to tile fit for easier installation with less cutting required. Figure 5 illustrates the effect of gaps on tile performance when installed with: no gap (**0mm**), **.25mm** and **1.0mm**. It is critical to maintain contact between tiles for best results. The final results of the completed test chamber will also be degraded by other factors such as lights, gaps around door openings, and exposed metallic conduit.

Wide Angle Absorption

One of the most overlooked aspects of using any absorber is the rolloff of absorption with increasing angle of incidence. Most published absorber data contains only normal incidence return loss (dB) which is typically where the maximum absorption is obtained. Normal incidence is defined as plane wave radiation arriving perpendicular (0°) to the plane of the absorbing surface. The curves in figure 4 were generated using equations described in IEEE document "Recommended Practice for RF Absorber Evaluation in the range 30 MHz to 5 GHz". Since the reflections occurring in anechoic chambers seldom illuminate absorber materials at 0° , it is important to consider the reflection angles generated by each chamber geometry and size for best results. For most chambers, the range of angles is in the 40-60° range, however it is usually desirable to operate at $< 50^\circ$.

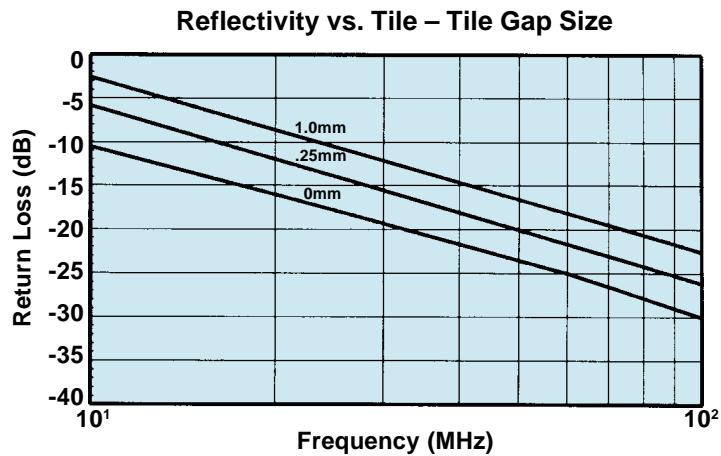


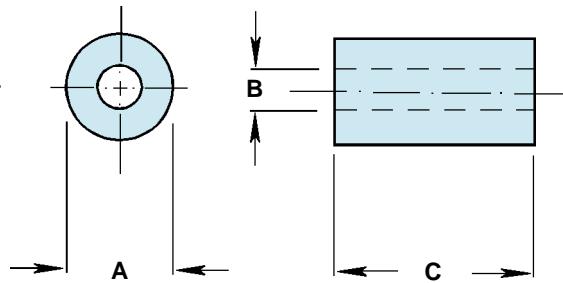
Figure 5

Shield Beads

Listed in ascending order of "B" dimension

Fair-Rite offers a broad selection of shield beads to guaranteed impedance specifications over a wide frequency range.

- Available materials: 73, 43, and 61.
- Beads with a "1" as the last digit of the part number are not burnished, those with the last digit "2" are supplied burnished to break the sharp edges.
- Beads can be supplied Parylene coated upon request. The last digit of Parylene coated parts is a "4". The minimum coating thickness for beads is **0.05mm (.0002")**. See page 6 for material characteristics of Parylene C.
- The "H" column gives for each bead size the calculated dc bias field in oersted for 1 turn and 1 ampere direct current. The actual dc H field in the application is this value of H times the actual NI (ampere - turn) product. For the effect of the dc bias on the impedance of the bead material, see the graphs on page 49 of this catalog.
- For performance data on shield beads, see pages 54 and 55 of section "How to Choose Ferrite Components for EMI Suppression".
- Beads are controlled for impedance limits only. They are tested for impedance with a single turn, using a Hewlett Packard HP 4193A Vector Impedance Meter for beads in 73 and 43 material and the HP 4191A RF Impedance Analyzer for 61 material beads.
- For any shield bead requirement not listed in the catalog, feel free to contact our customer service group for availability and pricing.



Dimensions (**Bold numbers** are in millimeters, light numbers are nominal in inches.)

Impedance(Ω)

Part Number**	A	B	C*	Wt (g)	H (Oe)	73		43		61	
						10 MHz	25 MHz	25 MHz	100 MHz	100 MHz	250 MHz
2673901301	0.95 - 0.05 .036	0.45+0.1 .020	3.8±0.2 .150	.01	6.0	13 Min.	24±20%	—	—	—	—
2673903301	1.0 - 0.05 .038	0.45+0.15 .021	5.6±0.25 .220	.01	5.7	19 Min.	35±20%	—	—	—	—
26 - - 004601	1.1 - 0.1 .041	0.65+0.1 .028	4.1 - 0.3 .156	.01	4.7	10 Min.	19±20%	10 Min.	31±20%	—	—
26 - - 004701	1.45 - 0.15 .054	0.7+0.1 .029	2.3±0.15 .090	.01	4.0	10 Min.	17±20%	10 Min.	26±20%	—	—
2643004101	3.5±0.2 .138	0.75+0.1 .031	4.45±0.35 .175	.11	2.6	—	—	39 Min.	70±20%	—	—
2643004201	3.5±0.2 .138	0.75+0.1 .031	8.9±0.5 .350	.22	2.6	—	—	78 Min.	140±20%	—	—
2673030101	1.22 - 0.13 .045	0.8+0.1 .033	5.3 - 0.45 .200	.01	4.1	9 Min.	17±20%	—	—	—	—
2673025301	1.25 - 0.1 .047	0.8+0.1 .033	3.8±0.2 .150	.01	4.0	8 Min.	15±20%	—	—	—	—
2673010101	1.95 - 0.25 .072	0.8+0.1 .033	10.0 - 0.4 .384	.08	3.3	44 Min.	77±20%	—	—	—	—
2643706001	3.5±0.25 .138	0.8+0.1 .033	2.7 - 0.45 .097	.06	2.5	—	—	21 Min.	45±20%	—	—
2673025001	1.42±0.05 .056	0.85+0.1 .034	3.8±0.2 .150	.02	3.6	10 Min.	20±20%	—	—	—	—
2643020501	1.65±0.025 .065	0.85+0.1 .034	3.68 - 0.25 .140	.02	3.4	—	—	17 Min.	35±20%	—	—

** Insert desired material in 3rd & 4th digit positions.

* This dimension may be modified to suit specific applications.

Fair-Rite Products Corp.

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(888) 324-7748 (888) 337-7483

One Commercial Row, Wallkill, NY 12589-0288

Shield Beads

Listed in ascending order of "B" dimension

Dimensions (*Bold numbers are in millimeters, light numbers are nominal in inches.*)

Impedance(Ω)

Part Number**	A	B	C*	Wt (g)	H (Oe)	73		43		61	
						10 MHz	25 MHz	25 MHz	100 MHz	100 MHz	250 MHz
26 - - 004801	2.1 - 0.15 .080	0.85+0.1 .034	2.9 - 0.45 .105	.03	3.1	16 Min.	28±20%	14 Min.	31±20%	—	—
2673028602	2.13 - 0.1 .082	0.85+0.1 .034	5.6±0.15 .220	.09	2.7	25 Min.	50±20%	—	—	—	—
2673012401	1.55 - 0.1 .059	0.95+0.15 .040	4.2 - 0.25 .160	.02	3.3	9 Min.	19±20%	—	—	—	—
26 - - 002201	1.95 - 0.2 .072	1.05+0.1 .043	10.4±0.25 .410	.08	2.9	30 Min.	55±20%	27 Min.	58±20%	—	—
26 - - 000501	2.0 - 0.15 .076	1.05+0.1 .043	1.65 - 0.25 .060	.01	2.8	7 Min.	12±20%	7 Min.	22±20%	—	—
26 - - 000201	2.0 - 0.15 .076	1.05+0.1 .043	3.8±0.25 .150	.03	2.8	15 Min.	27±20%	13 Min.	31±20%	—	—
26 - - 000101	3.5±0.2 .138	1.3±0.1 .051	3.25±0.25 .128	.10	2.0	28 Min.	33±20%	21 Min.	40±20%	22 Min.	43±20%
26 - - 000301	3.5±0.2 .138	1.3±0.1 .051	6.0±0.25 .236	.18	2.0	35 Min.	62±20%	37 Min.	60±20%	40 Min.	70±20%
26 - - 000701	3.5±0.2 .138	1.3±0.1 .051	12.7±0.35 .500	.38	2.0	70 Min.	125±20%	71 Min.	125±20%	100 Min.	170±20%
2643200101	5.1±0.25 .200	1.45+0.25 .062	3.4 - 0.45 .125	.19	1.5	—	—	24 Min.	41±20%	—	—
26 - - 022401	5.1±0.25 .200	1.45+0.25 .062	6.35±0.25 .250	.38	1.5	43 Min.	68±20%	44 Min.	82±20%	45 Min.	85±20%
26 - - 021801	5.1±0.25 .200	1.45+0.25 .062	11.1±0.35 .437	.67	1.5	75 Min.	120±20%	77 Min.	131±20%	95 Min.	163±20%
26 - - 023801	5.1±0.25 .200	1.45+0.25 .062	22.85±0.75 .900	1.4	1.5	—	—	154 Min.	266±20%	190 Min.	326±20%
2643001501	3.5±0.2 .138	1.6±0.1 .063	3.25±0.25 .128	.10	1.7	—	—	17 Min.	35±20%	—	—
2643025601	3.5±0.2 .138	1.6±0.1 .063	6.0±0.25 .236	.18	1.7	—	—	30 Min.	55±20%	—	—
2643023201	2.85±0.1 .112	1.65+0.15 .068	3.75±0.25 .147	.06	1.8	—	—	12 Min.	30±20%	—	—
2673018001	2.85±0.1 .112	1.65+0.15 .068	6.65±0.25 .262	.12	1.8	23 Min.	41±20%	—	—	—	—
2673004901	2.85±0.1 .112	1.65+0.15 .068	10.45±0.25 .410	.18	1.8	32 Min.	58±20%	—	—	—	—
2643013801	3.5±0.2 .138	1.65+0.25 .070	4.05±0.25 .160	.12	1.6	—	—	19 Min.	38±20%	—	—
26 - - 001601	3.55±0.15 .140	1.65+0.25 .070	3.3 - 0.4 .122	.09	1.6	13 Min.	24±20%	15 Min.	30±20%	—	—
2643001301	3.55±0.15 .140	1.65+0.25 .070	5.95±0.25 .234	.18	1.6	—	—	25 Min.	48±20%	—	—
2673015301	4.1 - 0.25 .156	1.8±0.15 .071	6.85±0.25 .270	.26	1.5	33 Min.	59±20%	—	—	—	—
2643005701	5.1±0.25 .200	2.3±0.2 .090	12.7±0.35 .500	.81	1.2	—	—	62 Min.	120±20%	—	—
26 - - 000801	7.5±0.25 .296	2.25+0.25 .094	7.55±0.25 .297	1.0	1.0	38 Min.	60±20%	50 Min.	92±20%	—	—
2643300101	7.6±0.25 .300	2.25+0.25 .094	15.1±0.75 .595	2.1	1.0	—	—	92 Min.	165±20%	—	—
2673200201	5.2±0.15 .205	2.65±0.25 .105	20.6±0.75 .812	1.3	1.1	70 Min.	125±20%	—	—	—	—
26 - - 003201	5.6 - 0.5 .210	2.65±0.25 .105	12.7±0.5 .500	.87	1.1	47 Min.	85±20%	50 Min.	88±20%	—	—
2643250402	6.35±0.15 .250	2.95+0.45 .125	12.7±0.5 .500	1.2	.91	—	—	55 Min.	102±20%	—	—
2643250302	6.35±0.15 .250	2.95+0.45 .125	15.9±0.5 .625	1.5	.91	—	—	68 Min.	122±20%	—	—
2643250202	6.35±0.15 .250	2.95+0.45 .125	25.4±0.75 1.000	2.5	.91	—	—	108 Min.	200±20%	—	—

** Insert desired material in 3rd & 4th digit positions.

* This dimension may be modified to suit specific applications.

Shield Beads

Listed in ascending order of "B" dimension

Dimensions (*Bold numbers are in millimeters, light numbers are nominal in inches.*)

Impedance (Ω)

Part Number	A	B	C*	Wt (g)	H (Oe)	73		43		61	
						10 MHz	25 MHz	25 MHz	100 MHz	100 MHz	250 MHz
2643375102	9.5±0.25 .375	4.5±0.75 .192	6.35±0.35 .250	1.4	.60	—	—	28 Min.	50±20%	—	—
2643375002	9.5±0.25 .375	4.5±0.75 .192	14.5±0.6 .570	3.1	.60	—	—	62 Min.	115±20%	—	—
2643006302	9.5±0.25 .375	4.75±0.3 .193	10.4±0.25 .410	2.2	.60	—	—	42 Min.	80±20%	—	—
2643023402	9.5±0.25 .375	4.75±0.3 .193	15.9±0.45 .625	3.4	.60	—	—	66 Min.	120±20%	—	—
2643023002	9.5±0.25 .375	4.75±0.3 .193	19.05±0.7 .750	4.1	.60	—	—	80 Min.	145±20%	—	—
2643002402	9.65±0.25 .380	5.0±0.2 .197	5.05 - 0.45 .190	1.1	.59	—	—	21 Min.	43±20%	—	—
2643480102	12.3±0.4 .485	4.95±0.25 .200	12.7±0.4 .500	4.8	.52	—	—	67 Min.	121±20%	—	—
2643480002	12.3±0.4 .485	4.95±0.25 .200	25.4±0.75 .1000	9.5	.52	—	—	132 Min.	236±20%	—	—
2643012702	9.65±0.15 .380	6.35±0.15 .250	7.35±0.25 .290	1.3	.51	—	—	19 Min.	38±20%	—	—
2643540702	14.3±0.45 .562	6.35±0.25 .250	5.3 - 0.45 .200	2.6	.43	—	—	24 Min.	50±20%	—	—
2643540102	14.3±0.45 .562	6.35±0.25 .250	10.15±0.4 .400	5.1	.43	—	—	49 Min.	89±20%	—	—
26 - - 540202	14.3±0.45 .562	6.35±0.25 .250	13.8 - 0.7 .530	6.8	.43	—	—	62 Min.	118±20%	100 Min.	180±20%
26 - - 540002	14.3±0.45 .562	6.35±0.25 .250	28.6±0.75 1.125	14	.43	—	—	137 Min.	250±20%	200 Min.	310±20%
26 - - 540302	14.3±0.45 .562	7.1±0.25 .280	15.25±0.4 .600	7.5	.41	—	—	60 Min.	118±20%	—	—
26 - - 800302	12.7±0.25 .500	7.15±0.2 .282	4.9 - 0.25 .188	1.7	.43	—	—	21 Min.	42±20%	—	—
2643540402	14.3±0.45 .562	7.25±0.15 .286	28.6±0.75 1.125	14	.40	—	—	114 Min.	215±20%	—	—
2643801102	12.7±0.25 .500	7.9±0.2 .312	6.35±0.2 .250	2.1	.40	—	—	21 Min.	41±20%	—	—
2643801902	12.7±0.25 .500	7.9±0.2 .312	12.7±0.4 .500	4.3	.40	—	—	35 Min.	73±20%	—	—
2643625002	16.25 - 0.75 .625	7.9±0.25 .312	14.3±0.35 .562	8.7	.36	—	—	56 Min.	113±20%	—	—
2643625102	16.25 - 0.75 .625	7.9±0.25 .312	28.6±0.75 1.125	17	.36	—	—	104 Min.	213±20%	—	—
2643625202	16.25 - 0.75 .625	7.9±0.25 .312	50.8±1.0 2.000	31	.36	—	—	188 Min.	384±20%	—	—
2643665902	17.45±0.4 .687	9.5±0.25 .375	6.35±0.25 .250	4.5	.32	—	—	21 Min.	44±20%	—	—
2643665802	17.45±0.4 .687	9.5±0.25 .375	12.7±0.5 .500	9.0	.32	—	—	44 Min.	88±20%	—	—
26 - - 665702	17.45±0.4 .687	9.5±0.25 .375	28.6±0.75 1.125	20	.32	—	—	100 Min.	200±20%	125 Min.	260±20%
2643626302	19.0 - 0.65 .735	10.15±0.25 .400	14.65 - 0.75 .562	12	.29	—	—	50 Min.	96±20%	—	—
2643626402	19.0 - 0.65 .735	10.15±0.25 .400	28.6±0.75 1.125	23	.29	—	—	102 Min.	196±20%	—	—
2643626502	19.0 - 0.65 .735	10.15±0.25 .400	50.8±1.0 2.000	41	.29	—	—	180 Min.	348±20%	—	—
2643801502	25.4±0.65 1.000	12.7±0.35 .500	6.35±0.25 .250	9.9	.23	—	—	27 Min.	53±20%	—	—
26 - - 102402	25.9±0.75 1.020	12.8±0.25 .505	21.3±0.5 .840	35	.22	—	—	88 Min.	183±20%	135 Min.	275±20%
26 - - 102002	25.9±0.75 1.020	12.8±0.25 .505	28.6±0.8 1.125	46	.22	—	—	116 Min.	235±20%	180 Min.	310±20%

*This dimension may be modified to suit specific applications.

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Shield Beads

Listed in ascending order of "B" dimension

Dimensions (*Bold numbers are in millimeters, light numbers are nominal in inches.*)

Impedance (Ω)

Part Number	A	B	C*	Wt (g)	H (Oe)	73		43		61	
						10 MHz	25 MHz	25 MHz	100 MHz	100 MHz	250 MHz
2643800602	20.95±0.4 .825	13.2±0.3 .520	6.35±0.2 .250	5.8	.24	—	—	19 Min.	44±20%	—	—
2643800502	20.95±0.4 .825	13.2±0.3 .520	11.9±0.4 .468	11	.24	—	—	36 Min.	82±20%	—	—
2643801802	22.1±0.4 .870	13.7±0.3 .540	6.35±0.2 .250	6.5	.23	—	—	20 Min.	45±20%	—	—
2643101902	28.5±0.6 1.122	13.8±0.3 .543	28.6±0.8 1.125	56	.21	—	—	116 Min.	230±20%	—	—
2643801402	25.4±0.6 1.000	15.5±0.5 .610	8.1±0.3 .320	11	.20	—	—	28 Min.	55±20%	—	—
2643806402	25.4±0.6 1.000	15.5±0.5 .610	12.7±0.4 .500	17	.20	—	—	42 Min.	90±20%	—	—
2643251002	39.1±0.75 1.540	16.75±0.5 .660	22.2±0.8 .875	84	.16	—	—	108 Min.	230±20%	—	—
2643801002	29.0±0.75 1.142	19.0±0.5 .748	7.5±0.25 .295	12	.17	—	—	22 Min.	47±20%	—	—
2643801202	29.0±0.75 1.142	19.0±0.5 .748	13.85±0.4 .545	23	.17	—	—	41 Min.	92±20%	—	—
2643804502	31.1±0.75 1.225	19.05±0.5 .750	16.3 - 0.75 .627	33	.17	—	—	48 Min.	100±20%	—	—
2643802702	35.55±0.75 1.400	22.85±0.5 .900	12.7±0.5 .500	32	.14	—	—	38 Min.	80±20%	—	—
2643626102	50.8±1.0 2.000	25.4±0.5 1.000	25.4±0.75 1.000	158	.11	—	—	102 Min.	224±20%	—	—
2643625902	50.8±1.0 2.000	25.4±0.5 1.000	28.7±0.75 1.130	178	.11	—	—	116 Min.	254±20%	—	—
2643626202	50.8±1.0 2.000	25.4±0.5 1.000	38.1±0.75 1.500	237	.11	—	—	154 Min.	336±20%	—	—
2643626002	50.8±1.0 2.000	25.4±0.5 1.000	50.8±1.0 2.000	315	.11	—	—	192 Min.	360±20%	—	—
2643803802	61.0±1.3 2.400	35.55±0.75 1.400	12.7±0.5 .500	105	.09	—	—	46 Min.	108±20%	—	—

*This dimension may be modified to suit specific applications.

Flat Cable Suppression Cores

Fair-Rite offers a line of flat cable suppression cores to attenuate radiated EMI emissions from ribbon cables. These cores, made from 43 material, can accommodate a range of cable sizes and conductors.

See pages 72 and 73 for nylon cases and steel and nylon clips to assist in the assembly of the split cable core halves.

- Available in 43 material.
- For performance data on Flat Cable Suppression Cores, see page 60 of section "How to Choose Ferrite Components for EMI Suppression."
- Cores are controlled for impedance limits only. They are tested for impedance with a single turn, using a Hewlett Packard HP 4193A Vector Impedance Meter.
- The Expanded Cable and Connector EMI Suppressor Kit (part number 0199000005) and the Fair-Rite EMI Suppressor Retro Kit (part number 0199000008) contain a selection of these suppression cores. See page 84.

Dimensions (**Bold numbers** are in millimeters, light numbers are nominal in inches.)

Impedance (Ω)

Part Number	Fig.	Max. Cable Width	A	B	C*	D	E	Wt (g)	25 MHz	100 MHz	Clip P/N**	Case P/N**
2643171351	5	.250	11.4±0.25 .450	6.6±0.15 .260	7.6±0.25 .300	3.3 - 0.25 .125	0.15±0.15 .009	1.4	40 Min.	80±20%	—	—
2643172751	3	.385	14.5±0.2 .571	10.0±0.13 .394	10.0±0.13 .394	2.5±0.15 .098	0.5±0.25 .025	1.5	25 Min.	59±20%	—	—
2643173851	3^	.480	16.5±0.25 .650	12.5±0.2 .492	10.25±0.25 .404	2.0±0.15 .079	0.5±0.25 .025	1.3	26 Min.	60±20%	—	—
2643170251	4	.490	22.75±0.65 .895	12.7±0.5 .500	12.7±0.5 .500	3.3 - 0.25 .125	1.15±0.25 .050	3.5	31 Min.	71±20%	—	—
2643169551	1	.550	19.95±0.4 .785	14.2±0.25 .560	10.15±0.5 .400	6.35±0.25 .250	0.9±0.15 .035	5.7	28 Min.	75±20%	—	—
2643168751	1	.680	25.4±0.75 1.000	17.8±0.5 .700	12.7±0.4 .500	10.15±0.25 .400	2.55±0.25 .100	13	35 Min.	85±20%	—	—
2643173351	2	.770	24.5±0.4 .965	20.0±0.4 .787	12.0±0.3 .472	5.0±0.25 .197	0.75±0.25 .030	6.6	25 Min.	55±20%	—	—
2643168651	4	1.010	38.85±0.75 1.530	26.15±0.75 1.030	28.6±0.7 1.125	13.0±0.3 .512	6.35±0.25 .255	45	80 Min.	185±20%	—	—
2643164551	1	1.030	38.1±1.0 1.500	26.65±0.75 1.050	12.3±0.4 .485	12.05±0.4 .475	1.9±0.4 .075	25	38 Min.	98±20%	—	—
2643171051	3	1.030	38.1±1.0 1.500	26.65±0.75 1.050	12.7±0.4 .500	6.35±0.25 .250	0.85±0.2 .033	14	40 Min.	105±20%	0199001401 0199016051	—
2643163851	1	1.030	38.1±1.0 1.500	26.65±0.75 1.050	25.4±0.75 1.000	12.05±0.4 .475	1.9±0.4 .075	51	76 Min.	195±20%	—	—
2643166851	3	1.030	38.1±1.0 1.500	26.65±0.75 1.050	25.4±0.75 1.000	6.35±0.25 .250	0.85±0.2 .033	27	80 Min.	210±20%	0199001401	—
2643172551	2	1.040	33.5±0.65 1.319	27.0±0.5 1.063	8.0±0.4 .315	6.5±0.25 .256	1.25±0.7 .063	6.8	14 Min.	42±20%	—	—
2643169351	1	1.060	33.65±0.75 1.325	27.5±0.5 1.083	13.2±0.5 .520	6.7±0.4 .265	1.35±0.25 .053	12	28 Min.	75±20%	—	—
2643167051	3^	1.080	40.9±0.75 1.600	28.2±0.75 1.100	12.7±0.25 .500	15.0±0.25 .590	8.5±0.15 .335	23	37 Min.	88±20%	—	—
2643166451	3	1.080	38.35±1.0 1.510	27.95±1.0 1.100	28.6±0.7 .1125	9.0±0.3 .355	3.3±0.25 .130	35	72 Min.	170±20%	0199010301	—
2643168051	3^	1.280	52.9±1.0 2.083	33.0±0.7 1.299	31.25±1.0 1.230	12.5±0.4 .492	3.5±0.4 .138	84	106 Min.	243±20%	—	—
2643167551	3^	1.280	52.9±1.0 2.083	33.0±0.7 1.299	63.5±1.8 2.500	12.5±0.4 .492	3.5±0.4 .138	170	210 Min.	460±20%	—	—

* This dimension may be modified to suit specific applications.

^ Part does not have clip slots as shown in figure.

** Refer to pages 72 and 73 for dimensions and figures for Flat Cable Suppression Core Clips and Cases.

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Flat Cable Suppression Cores

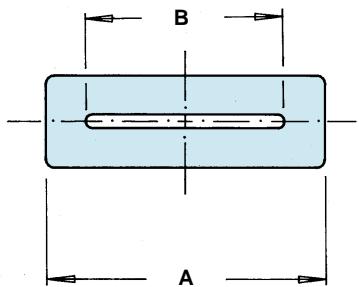


Figure 1

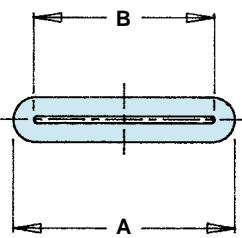
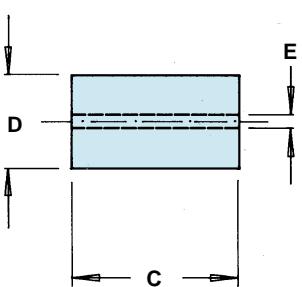


Figure 2

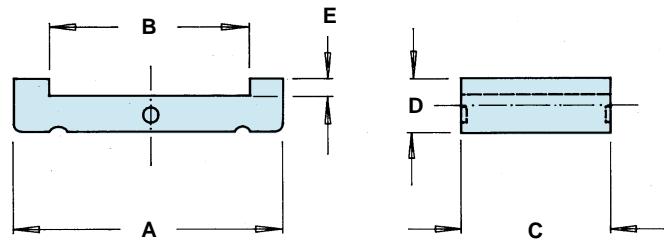
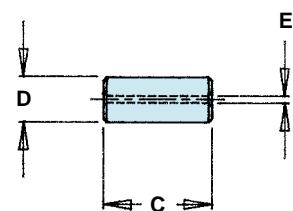


Figure 3

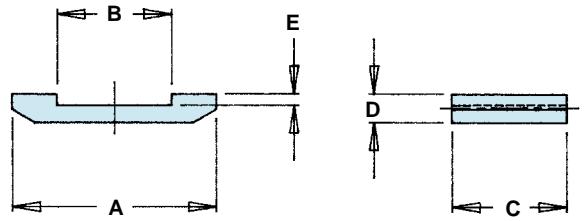


Figure 4

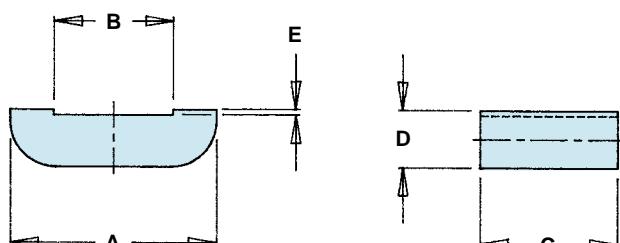


Figure 5

Flat Cable Suppression Cores

Dimensions (*Bold numbers are in millimeters, light numbers are nominal in inches.*)

Impedance (Ω)

Part Number	Fig.	Max. Cable Width	A	B	C*	D	E	Wt (g)	25 MHz	100 MHz	Clip P/N**	Case P/N**
2643170951	3	1.330	45.1±0.75 1.775	34.4±0.7 1.355	12.7±0.4 .500	6.35±0.25 .250	0.85±0.2 .033	16	34 Min.	100±20%	0199001401 0199016051	—
2643166551	1	1.330	45.1±0.75 1.775	34.4±0.7 1.355	28.6±0.7 1.125	12.45±0.4 .490	1.5±0.3 .060	71	76 Min.	195±20%	—	0199166651
2643166651	3	1.330	45.1±0.75 1.775	34.4±0.7 1.355	28.6±0.7 1.125	6.35±0.25 .250	0.85±0.2 .033	36	77 Min.	225±20%	0199001401 0199016551	0199166651
2643168251	3	2.030	63.5±1.3 2.500	52.1±1.1 2.050	12.7±0.4 .500	6.35±0.25 .250	0.85±0.2 .033	22	31 Min.	104±20%	0199001401 0199016051	—
2643163951	3	2.030	63.5±1.3 2.500	52.1±1.1 2.050	28.6±0.8 1.125	6.35±0.25 .250	0.85±0.2 .033	50	70 Min.	235±20%	0199001401 0199016551	0199163951
2643167751	3	2.550	76.2±1.5 3.000	65.3±1.3 2.570	12.7±0.4 .500	6.35±0.25 .250	0.85±0.2 .033	27	29 Min.	110±20%	0199001401 0199016051	—
2643164051	3	2.550	76.2±1.5 3.000	65.3±1.3 2.570	28.6±0.8 1.125	6.35±0.25 .250	0.85±0.2 .033	60	60 Min.	215±20%	0199001401 0199016551	0199164051
2643171151	3	3.060	88.9±1.8 3.500	78.2±1.5 3.080	12.7±0.4 .500	6.5±0.35 .256	0.95±0.3 .037	31	26 Min.	95±20%	0199001401 0199016051	—
2643168351	3	3.060	88.9±1.8 3.500	78.2±1.5 3.080	28.6±0.8 1.125	6.5±0.35 .256	0.95±0.3 .037	70	60 Min.	215±20%	0199001401 0199016551	—

* This dimension may be modified to suit specific applications.

** Refer to pages 72 and 73 for dimensions and figures for Flat Cable Suppression Core Clips and Cases.

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Flat Cable Suppression Cores

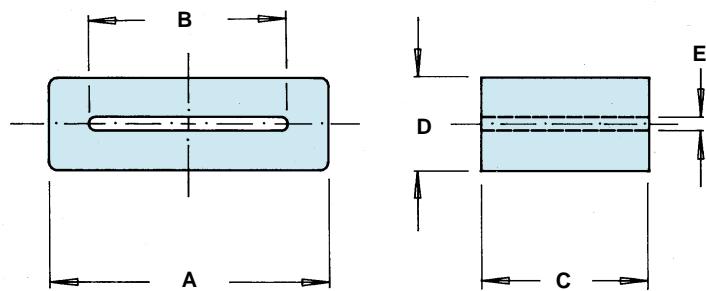


Figure 1

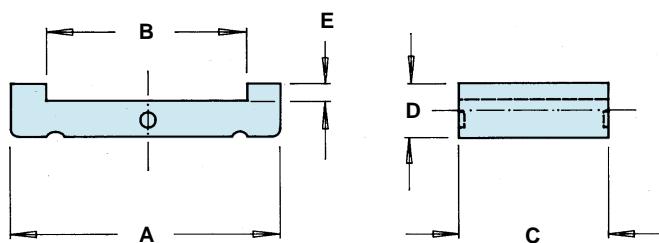


Figure 3

Flat Cable Suppression Cores

Cases

Dimensions (**Bold numbers** are in millimeters, light numbers are in inches.)

Part Number Case	Fig.	A	B	C	D	E	Case Material	Part Number Case & 2 Ferrite Parts
0199166651	1	49.5 1.950	34.3 1.350	32.3 1.272	8.1 .320	20.0 .787	Nylon 6/6 Flammability Rating: UL94-V2	0443166651
0199163951	1	67.8 2.670	52.6 2.070	32.3 1.272	8.1 .320	38.0 1.496	Nylon 6/6 Flammability Rating: UL94-V2	0443163951
0199164051	1	80.8 3.180	65.5 2.580	32.3 1.272	8.1 .320	50.8 2.000	Nylon 6/6 Flammability Rating: UL94-V2	0443164051

Clips

Dimensions (**Bold numbers** are in millimeters, light numbers are in inches.)

Part Number Clip	Fig.	A	B	C	D	E	F	G	H	J	Clip Material
0199001401	2	16.1 .635	11.0 .433	12.7 .500	11.4 .450	8.0 .315	—	—	—	—	0.5 (.020) High Carbon Steel Finish: Zinc Electroplate
0199010301	3	21.2 .835	11.0 .433	12.7 .500	16.5 .650	8.0 .315	7.5 .295	4.0 .157	6.0 .236	3.0 .118	0.5 (.020) High Carbon Steel Finish: Zinc Electroplate
0199016051	4	16.7 .657	15.9 .626	15.9 .626	24.6 .969	4.35 .171	3.2 .126	6.4 .252	—	—	Nylon 6/6 Flammability Rating: UL94-V2
0199016551	4	16.7 .657	32.2 1.27	15.9 .626	40.5 1.59	4.35 .171	3.2 .126	6.4 .252	—	—	Nylon 6/6 Flammability Rating: UL94-V2

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Flat Cable Suppression Cores

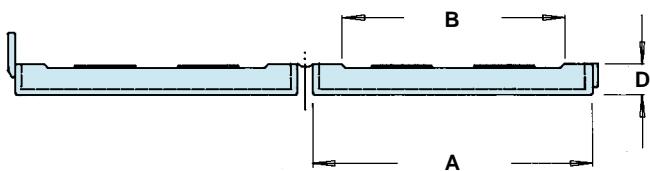
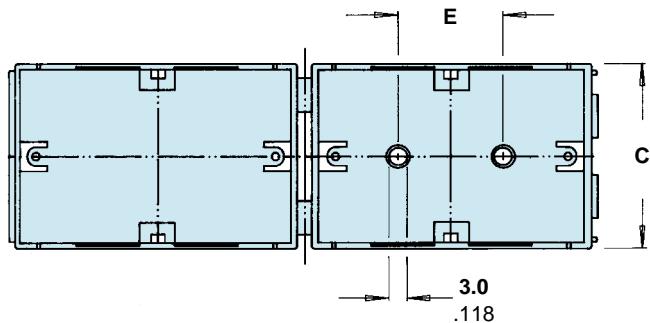


Figure 1

Case has rows of serrated teeth that grip and center the core around the cable. (Patented)

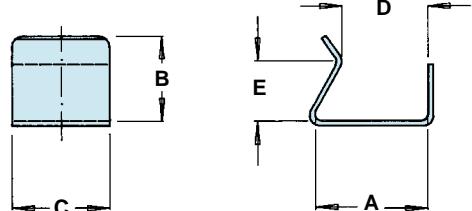


Figure 2

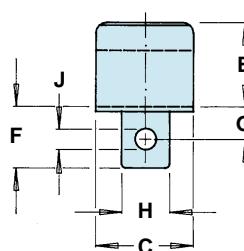


Figure 3

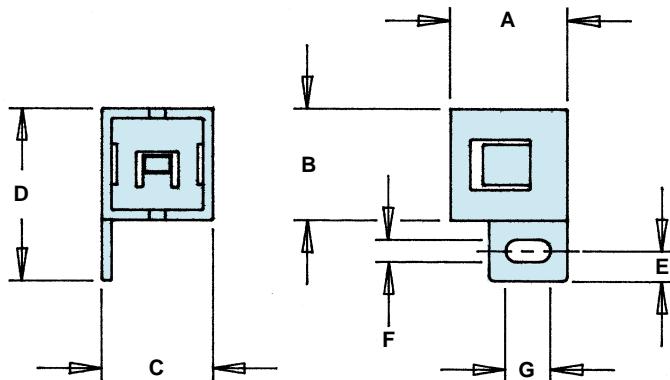


Figure 4

Round Cable Suppression Cores

Suppression cores for round cables are available for a range of cable diameters. Installed around a cable, these 43 and 44 material cores, attenuate any form of EMI emission.

Nylon cases make the assembly of the core halves a snap. Cores are easily installed in equipment where a retrofit proves necessary. See pages 76 and 77 for available nylon cases.

- Available materials: 43 and 44
- For performance data on Round Cable Suppression Cores, see page 60 of section "How to Choose Ferrite Components for EMI Suppression".
- Cores are controlled for impedance limits only. They are tested for impedance with a single turn, using a Hewlett Packard HP 4193A Vector Impedance Meter.
- The Expanded Cable and Connector EMI Suppressor Kit (part number 0199000005) and the Fair-Rite EMI Suppressor Retro Kit (part number 0199000008) contain a selection of these suppression cores. See page 84.

Dimensions (*Bold numbers are in millimeters, light numbers are nominal in inches.*)

Part Number	Fig.	Max. Cable Diameter	Impedance (Ω)								
			A	B	C	D	Wt (g)	25 MHz	100 MHz	Case P/N*	Case Fig.*
2643166751	1	.100	7.65 - 0.25 .485	2.3+0.25 .200	7.8 - 0.5 1.000	3.9 - 0.25 .242	1.1	48 Min.	93±20%	—	—
2643165451	1	.250	15.0±0.25 .590	6.6±0.3 .260	15.25±0.6 .600	7.5±0.15 .295	7.3	75 Min.	155±20%	—	—
2643164251	1	.250	15.0±0.25 .590	6.6±0.3 .260	28.6±0.8 1.125	7.5±0.15 .295	14	130 Min.	275±20%	0199164251	1
2643625006	2	.300	15.9±0.4 .626	7.9±0.3 .311	14.3±0.4 .563	7.95±0.2 .313	5.0	40 Min.	113±20%	0199625006	2
2643665806	2	.365	17.5±0.5 .689	9.5±0.3 .374	12.7±0.4 .500	8.75±0.25 .344	5.2	33 Min.	88±20%	0199665806	2
2643167251	1	.390	18.65±0.4 .735	10.15±0.3 .400	28.6±0.8 1.125	9.4±0.15 .370	18	110 Min.	225±20%	0199167251	1
2643800506	2	.500	21.0±0.5 .827	13.2±0.4 .520	11.9±0.4 .469	10.5±0.25 .413	6.0	28 Min.	75±20%	0199800506	2
2643164151	1	.500	25.9±0.5 1.020	13.05±0.3 .514	28.6±0.8 1.125	12.95±0.25 .510	38	125 Min.	250±20%	0199164151	1
2643806406	2	.590	25.4±0.6 1.000	15.5±0.5 .610	12.7±0.4 .500	12.7±0.3 .500	9.7	34 Min.	90±20%	0199806406	2
2644173551	1	.720	25.9±0.5 1.020	18.8±0.3 .740	38.9±0.4 1.532	13.0±0.25 .512	33	75 Min.	194±20%	0199173551	1

* Refer to pages 76 and 77 for dimensions and figures for Round Cable Suppression Core Cases.

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Round Cable Suppression Cores

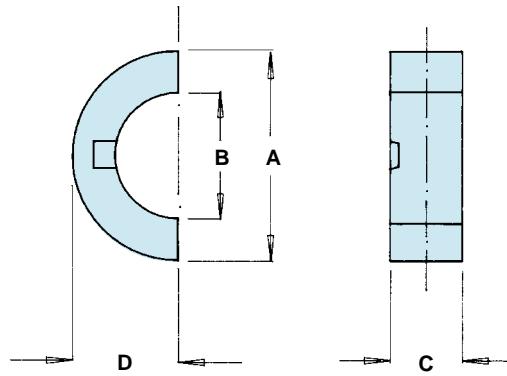
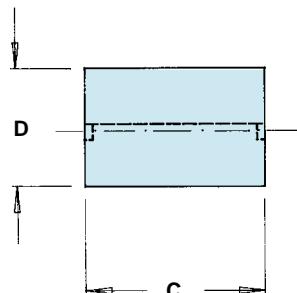
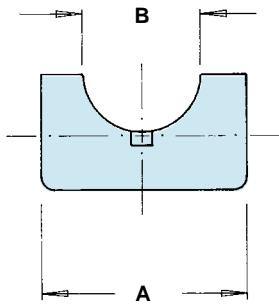


Figure 1

Figure 2

Round Cable Suppression Cores

Cases

Dimensions (**Bold numbers** are in millimeters, light numbers are in inches.)

Part Number Case	Fig.	A	B	C	D	E	Case Material	Part Number Case & 2 Ferrite Parts
0199164251	1	17.9 .705	7.0 .275	32.3 1.272	9.2 .362	9.0 .354	Nylon 6/6 Flammability Rating: UL94-V2	0443164251
0199167251	1	22.1 .870	10.2 .402	32.3 1.272	11.7 .461	9.0 .354	Nylon 6/6 Flammability Rating: UL94-V2	0443167251
0199164151	1	29.0 1.142	13.4 .528	32.5 1.280	14.8 .583	18.0 .709	Nylon 6/6 Flammability Rating: UL94-V2	0443164151
0199173551	1	29.2 1.150	19.4 .764	42.0 1.65	14.7 .579	—	Nylon 6/6 Flammability Rating: UL94-V2	0444173551
0199625006	2	24.7 .972	7.6 .299	22.8 .898	10.2 .402	17.8 .701	Nylon 6/6 Flammability Rating: UL94-V2	0443625006
0199665806	2	26.3 1.035	9.2 .362	21.4 .843	11.0 .433	16.4 .646	Nylon 6/6 Flammability Rating: UL94-V2	0443665806
0199800506	2	29.7 1.169	12.8 .504	20.6 .811	12.7 .500	15.6 .614	Nylon 6/6 Flammability Rating: UL94-V2	0443800506
0199806406	2	34.3 1.350	15.0 .591	21.2 .835	15.0 .591	16.2 .638	Nylon 6/6 Flammability Rating: UL94-V2	0443806406

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Round Cable Suppression Cores

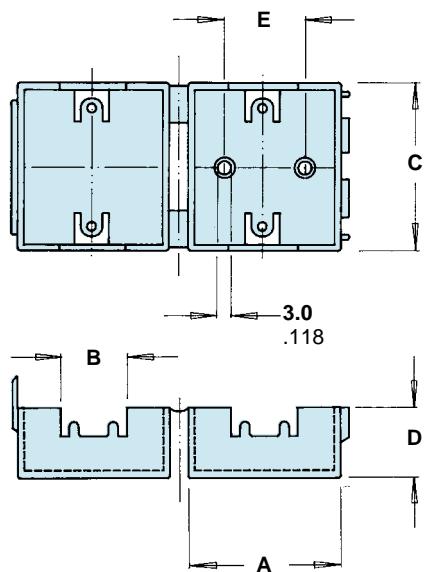


Figure 1

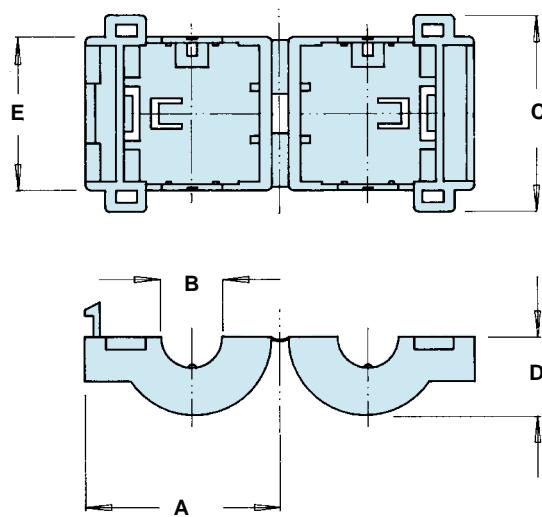


Figure 2

Connector Suppression Plates

To reduce conducted EMI, "D" type and DIP/Connector suppression plates are available in several sizes and pin layouts.

- Available in 44 material.
- For performance data on Connector Suppression Plates, see page 61 of section "How to Choose Ferrite Components for EMI Suppression".
- Impedance specification applies to all holes. They are tested for impedance with a single turn, using a Hewlett Packard HP 4193A Vector Impedance Meter.
- The Expanded Cable and Connector EMI Suppressor Kit (part number 0199000005) contains a selection of these cores. See page 84.

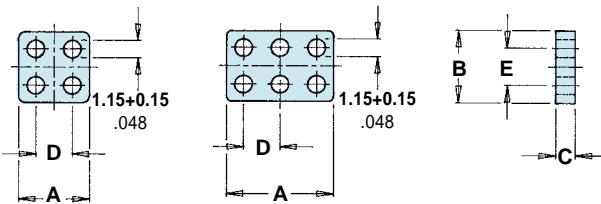


Figure 1-A

Figure 1-B

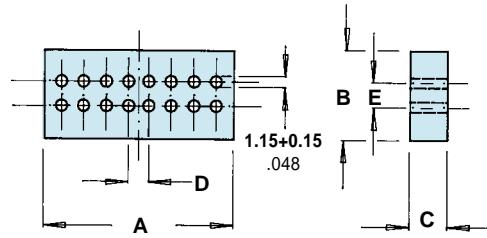


Figure 2

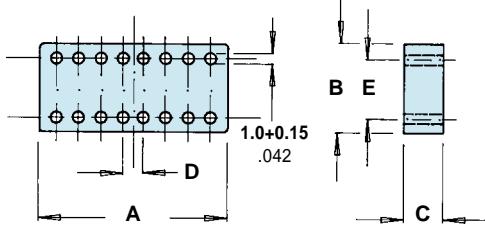


Figure 3

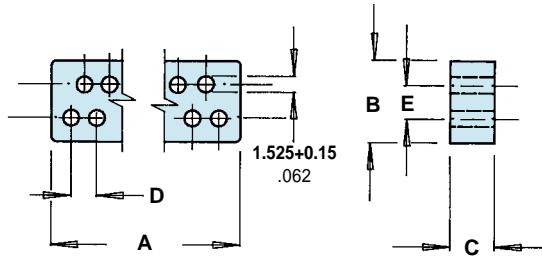


Figure 4

Dimensions (**Bold** numbers are in millimeters, light numbers are nominal in inches.)

Impedance (Ω)

Part Number	Fig.	Number of Holes	A	B	C*	D	E	Wt (g)	25 MHz	100 MHz
2644245901	1-A	4	4.9±0.13 .193	4.9±0.13 .193	1.65 - 0.25 .060	2.54±0.1 .100	2.54±0.1 .100	.2	10 Min.	22 Min.
2644245601	1-A	4	4.9±0.13 .193	4.9±0.13 .193	6.6 - 0.5 .250	2.54±0.1 .100	2.54±0.1 .100	.8	33 Min.	53 Min.
2644245701	1-B	6	7.45±0.13 .293	4.9±0.13 .193	1.65 - 0.25 .060	2.54±0.1 .100	2.54±0.1 .100	.3	10 Min.	22 Min.
2644245801	1-B	6	7.45±0.13 .293	4.9±0.13 .193	6.6 - 0.5 .250	2.54±0.1 .100	2.54±0.1 .100	1.2	33 Min.	53 Min.
2644373841	2	16	20.3±0.5 .800	9.95±0.2 .392	3.3 - 0.25 .125	2.54±0.1 .100	2.54±0.1 .100	2.9	24 Min.	41 Min.
2644373941	3	16	21.6±0.5 .850	11.45±0.25 .450	1.65 - 0.25 .060	2.54±0.1 .100	7.5±0.25 .300	1.6	15 Min.	29 Min.
2644236101	4	9	14.4±0.15 .567	7.75 - 0.25 .300	3.55 - 0.25 .135	2.75±0.1 .108	2.85±0.1 .112	1.5	24 Min.	41 Min.
2644236401	4	9	14.4±0.15 .567	7.75 - 0.25 .300	7.1 - 0.5 .270	2.75±0.1 .108	2.85±0.1 .112	3.1	45 Min.	73 Min.
2644236301	4	15	22.55±0.25 .888	7.75 - 0.25 .300	3.55 - 0.25 .135	2.75±0.1 .108	2.85±0.1 .112	2.3	24 Min.	41 Min.
2644236501	4	15	22.55±0.25 .888	7.75 - 0.25 .300	7.1 - 0.5 .270	2.75±0.1 .108	2.85±0.1 .112	4.6	45 Min.	73 Min.
2644236001	4	25	36.3±0.4 1.430	7.75 - 0.25 .300	3.55 - 0.25 .135	2.75±0.1 .108	2.85±0.1 .112	3.6	24 Min.	41 Min.
2644236601	4	25	36.3±0.4 1.430	7.75 - 0.25 .300	7.1 - 0.5 .270	2.75±0.1 .108	2.85±0.1 .112	7.2	45 Min.	73 Min.

* This dimension may be modified to suit specific applications.

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Miscellaneous Suppression Cores

Fair-Rite has tooled several core geometries for use as EMI attenuators.

- Available in 43 material.
- For technical information on Miscellaneous Suppression Cores, see section "How to Choose Ferrite Components for EMI Suppression" found on page 42.
- Cores are controlled for impedance limits only. They are tested for impedance with a single turn, using a Hewlett Packard HP 4193A Vector Impedance Meter.

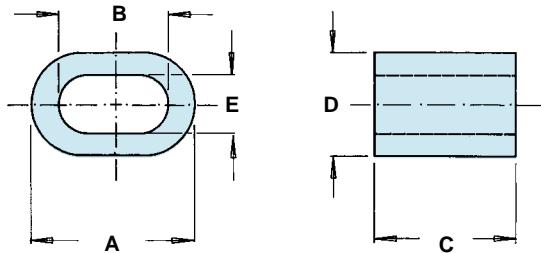


Figure 1

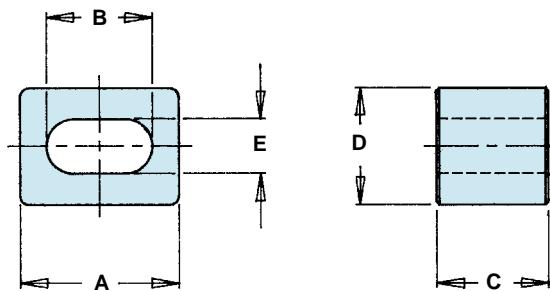


Figure 2

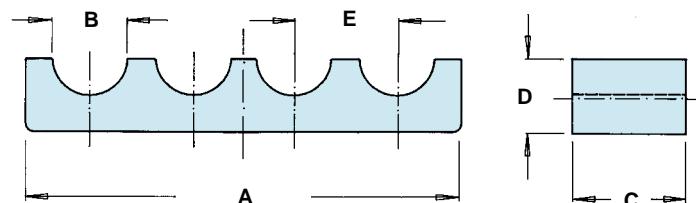


Figure 3

Dimensions (Bold numbers are in millimeters, light numbers are nominal in inches.)

Impedance (Ω)

Part Number	Fig.	A	B	C*	D	E	Wt (g)	25 MHz	100 MHz
2643167851	1	38.85±0.75 1.530	26.15±0.75 1.030	28.6±0.7 1.125	26.0±0.6 1.025	12.95±0.25 .510	85	75 Min.	135 Min.
2643166251	2	26.7±0.7 1.052	17.8±0.5 .701	18.8±0.4 .740	19.5±0.5 .770	9.15±0.50 .360	34	60 Min.	96 Min.
2643165151	3	82.6±1.6 3.250	13.1±0.3 .516	28.0±0.7 1.100	12.95±0.25 .510	19.05±0.4 .750	109	130 Min.	225 Min.

* This dimension may be modified to suit specific applications.

SM Beads

Surface mount beads and common-mode surface mount beads are available from Fair-Rite in several sizes. Their rugged construction decreases dc resistance and increases current carrying capacity compared with plated beads.

The Common-Mode surface mount bead provides a common path for the magnetic flux generated by the current to the load and the return current from the load. The current compensation results in zero magnetic flux in the core.

- Available materials: 43, 44 and 73.
- 12mm taped SM Beads are supplied taped and reeled per EIA Standard 481-1-A and IEC 286-3. 16mm and 24mm taped SM Beads are supplied taped and reeled per EIA Standard 481-2 and IEC 286-3.
- Parts can also be supplied not taped and reeled and then are bulk packed. This packing method will change the last digit of the part number to a "6".
- The copper conductors have a 30-60 μ inch nickel barrier and a minimum 95/5 tin/lead coating thickness of 200 μ inch.
- SM Beads meet the solderability specifications when tested in accordance with MIL-STD-202, method 208. After dipping the mounting side of the bead, the solder surface shall be at least 95% covered with a smooth solder coating. The edges of the copper strip are not specified as solderable surfaces.
- After preheating the beads to within 100°C of the soldering temperature, the parts meet the resistance to soldering requirements of EIA-186-10E, temperature 260 \pm 5°C and time 10 \pm 1 seconds.
- Suggested land patterns are in accordance with the recommendations of "Surface Mount Land Patterns (Configuration and Design Rules) ANSI/IPC-SM-782".
- For performance data on SM Beads, see pages 56 and 57 of section "How to Choose Ferrite Components for EMI Suppression".
- SM Beads are controlled for impedance limits only. They are tested for impedance with a single turn, using a Hewlett Packard HP 4191A RF Impedance Analyzer with spring clip fixture HP 16092A. The 274455577 wound bead is tested for impedance using a Hewlett Packard 4191A RF Impedance Analyzer with spring clip fixture HP 16092A.
- The maximum current rating for these beads is 5 amps.
- Common-mode beads can withstand a minimum breakdown voltage of 500VDC.
- The Surface Mount Bead Kit (part number 0199000014) is available for prototype evaluation. See page 84.

Dimensions (**Bold** numbers are in millimeters, light numbers are nominal in inches.)

Part Number*	Fig.	A	B	C	D	E	Wt (g)	Tape Width	Parts/Reel
27 - 019447	1	2.85\pm0.2 .112	3.05\pm0.1 .120	5.1 - 0.85 .184	1.5\pm0.5 .059	—	.15	12	2800
27 - 021447	1	2.85\pm0.2 .112	3.05\pm0.1 .120	9.6 - 0.95 .359	1.5\pm0.5 .059	—	.30	16	2800
27 - 037447	1	2.70\pm0.2 .106	4.6\pm0.2 .181	9.25 - 0.7 .350	1.2\pm0.2 .047	—	.45	16	2800
27 - 044447	1	1.52 Max. .060 Max.	3.1\pm0.1 .122	5.65\pm0.45 .222	1.55\pm0.25 .061	—	.09	12	4500
2744041447	2	2.85\pm0.2 .112	5.6\pm0.2 .220	5.0 - 0.6 .185	1.35\pm0.25 .053	2.54\pm0.1 .100	.30	12	2400
2744045447	2	2.85\pm0.2 .112	5.6\pm0.2 .220	8.9 - 0.8 .335	1.35\pm0.25 .053	2.54\pm0.1 .100	.53	16	2400

* Insert desired material in 3rd & 4th digit positions.

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SM Beads

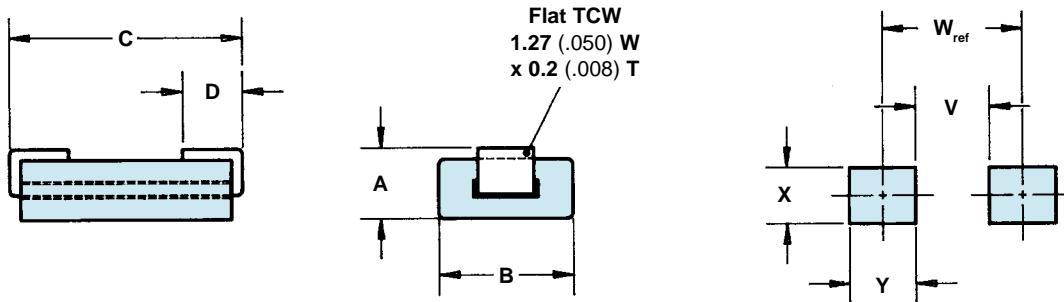


Figure 1

Land Pattern

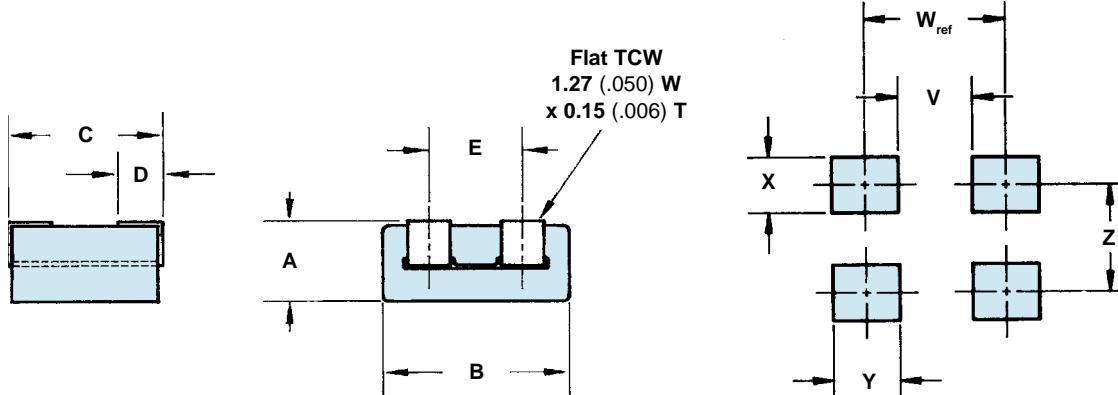


Figure 2

Land Pattern

Dimensions (**Bold numbers** are in millimeters, light numbers are in inches.)

Impedance (Ω)

Land Pattern Dimensions

Part Number*	73		43		44		Rdc(m Ω)	V	W(ref.)	X	Y	Z
	10 MHz	25 MHz	25 MHz	100 MHz	25 MHz	100 MHz						
27- - 019447	25 Min.	40±20%	23 Min.	47±20%	—	—	0.6 Max.	1.0 .040	4.0 .157	1.8 .071	3.0 .118	—
27- - 021447	48 Min.	78±20%	45 Min.	95±20%	—	—	0.9 Max.	4.5 .177	7.5 .295	1.8 .071	3.0 .118	—
27- - 037447	48 Min.	78±20%	45 Min.	95±20%	—	—	0.7 Max.	5.0 .197	8.0 .315	1.8 .071	3.0 .118	—
27- - 044447	20 Min.	33±20%	—	—	17 Min.	36±20%	0.8 Max.	1.5 .059	4.5 .177	1.8 .071	3.0 .118	—
2744041447	—	—	—	—	16 Min.	33±20%	0.8 Max.	1.0 .040	4.0 .157	1.8 .071	3.0 .118	2.54 .100
2744045447	—	—	—	—	30 Min.	60±20%	1.2 Max.	4.5 .177	7.5 .295	1.8 .071	3.0 .118	2.54 .100

* Insert desired material in 3rd & 4th digit positions.

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SM Beads

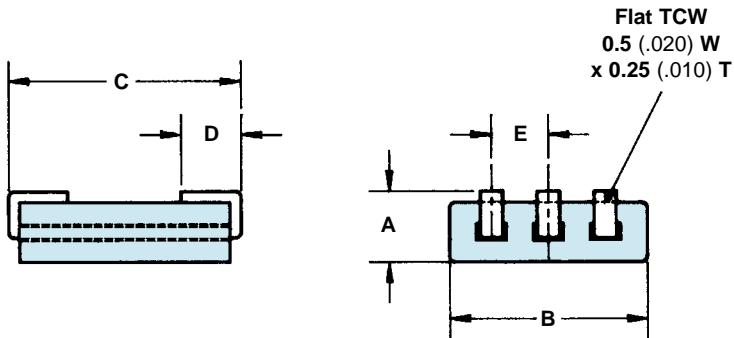


Figure 3

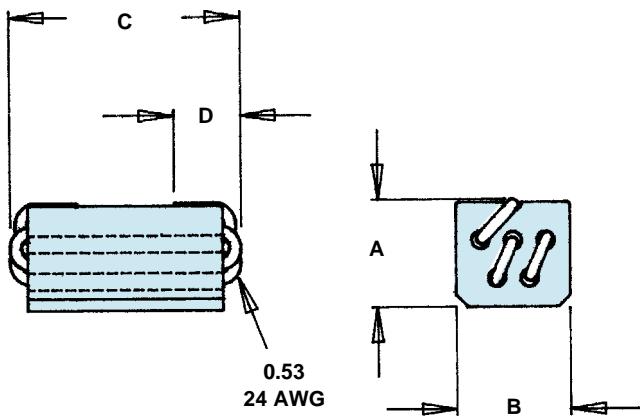


Figure 4

Dimensions (**Bold numbers** are in millimeters, light numbers are nominal in inches.)

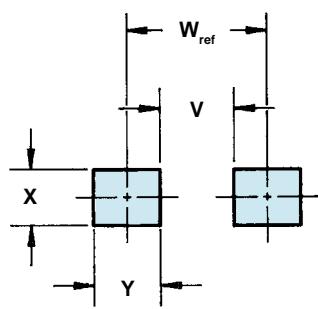
Part Number	Fig.	A	B	C	D	E	Wt (g)
2744040446**	3	1.45±0.2 .057	4.5±0.2 .177	6.2 - 0.6 .232	1.4±0.4 .055	1.27±0.05 .050	.14
2744555577	4	5.0 Max. .197 Max.	5.00±0.25 .197	11.0 Max. .433 Max.	2.0 Min. .079 Min.	—	.96

** Not supplied taped and reeled.

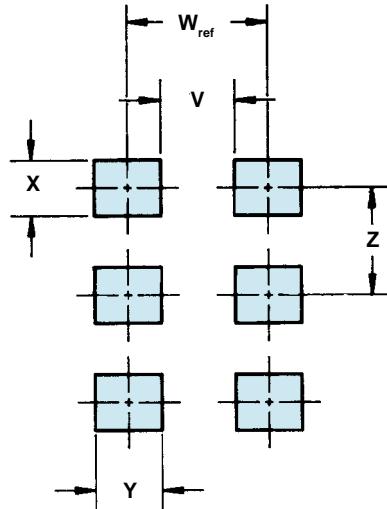
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SM Beads



Land Pattern
Figure 1



Land Pattern
Figure 2

Dimensions (*Bold numbers are in millimeters, light numbers are in inches.*)

Impedance (Ω)

Land Pattern Dimensions

Part Number	25 MHz	100 MHz	Rdc(m Ω)	Fig.	V	W(ref.)	X	Y	Z
2744040446	23 Min.	56±20%	1.4 Max.	1	1.8 .071	4.8 .189	0.8 .032	3.0 .118	1.27 .050
2744555577	340 Min.	600±20%	7.5 Max.	2	2.0 .079	7.0 .276	2.0 .079	5.0 .197	—

Engineering Kits

Engineering Evaluation Kits

In order to assist the design engineer concerned with EMI suppression, Fair-Rite was the first ferrite manufacturer to offer engineering evaluation kits. These kits are designed to reflect the different mechanical and frequency requirements of all types of suppression applications. Each kit contains a sampling of suppression cores for use in the original design phase or in situations where a retrofit proves necessary.

Bead, Balun and Broadband Kit II.

Part Number 0199000011.

This kit is the latest version of the first engineering kit introduced in 1978. It has an assortment of 34 parts, consisting of small shield beads, beads on leads and multi-aperture cores. To obtain optimum performance over a broad frequency spectrum, samples are supplied in several Fair-Rite materials.

Expanded Cable and Connector EMI Suppressor Kit.

Part Number 0199000005.

This is our most popular engineering kit. As the name implies, this kit provides a broad sampling of suppression cores, specifically designed to attenuate EMI between all types of cable connected systems. To assemble the split cable suppression cores, nylon cases and steel clips are included in this kit.

Expanded Bead-on-Lead EMI Suppressor Kit.

Part Number 0199000010.

Twenty-four wired beads in three basic design geometries are included in this evaluation kit. These beads are supplied in three suppressor materials; 73, 43 and 61.

Fair-Rite EMI Suppressor Retro Kit.

Part Number 0199000008.

This evaluation kit contains two sets each of ten different split cable suppression cores, installed in their appropriate nylon cases. This evaluation kit will prove particularly useful in new and existing designs, that use flat or round connecting cables, where EMI attenuation is required.

Fair-Rite Surface Mount Bead Kit.

Part Number 0199000014.

Twelve surface mount beads in five geometries are in this engineering kit. These SM beads are for use in differential and common-mode applications. Our suppression materials 43, 44 and 73 are all included in this kit.

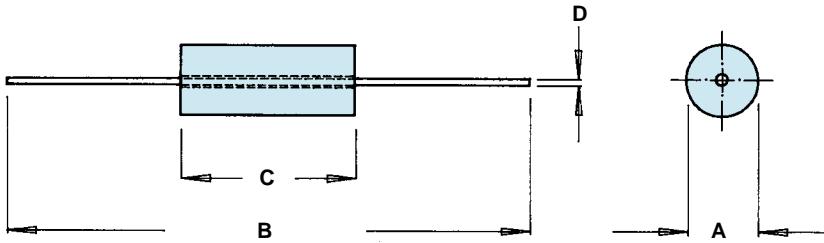


These five Fair-Rite engineering evaluation kits, priced at \$ 60.- each, are available from Fair-Rite in Wallkill, NY. They can also be purchased from our distributors. See the back cover of this catalog for a complete listing of our distributors.

Beads on Leads

Shield beads are supplied assembled on tinned copper wire to aid automated circuit assembly.

- Available materials: 73, 43, and 61.
- Parts with a "2" as the last digit of the part number are supplied taped and reeled per IEC 286-1 and EIA Standard 296-E. Inside tape spacing is **52.4±1.5 mm**. These parts can also be supplied not taped and reeled and are then bulk packed. The last digit of bulk packaged parts is "1".
- Wires are oxygen free high conductivity copper with a 95/5 tin/lead coating.
- For performance data on these parts, see page 53 of section "How to Choose Ferrite Components for EMI Suppression".
- Beads are controlled for impedance limits only. They are tested for impedance with a single turn, using a Hewlett Packard HP 4193A Vector Impedance Meter for beads in 73 and 43 material and the HP 4191A RF Impedance Analyzer for 61 material beads.
- The Expanded Bead-on-Lead EMI Suppressor Kit (part number 0199000010) is available for prototype evaluation. See page 84.



Dimensions (*Bold numbers are in millimeters, light numbers are nominal in inches.*)

Impedance (Ω)

Part Number*	A	B	C	D	Wt (g)	73		43		61	
						10 MHz	25 MHz	25 MHz	100 MHz	100 MHz	250 MHz
27 - - 001112	3.5±0.25 .138	62.0±1.5 2.440	4.45±0.25 .175	0.65 22 AWG	.4	38 Min.	61±20%	39 Min.	68±20%	45 Min.	80±20%
27 - - 015112	3.5±0.25 .138	62.0±1.5 2.440	5.25±0.25 .206	0.65 22 AWG	.4	44 Min.	68±20%	43 Min.	82±20%	55 Min.	100±20%
27 - - 005112	3.5±0.25 .138	62.0±1.5 2.440	6.0±0.25 .236	0.65 22 AWG	.4	50 Min.	78±20%	48 Min.	91±20%	60 Min.	113±20%
27 - - 003112	3.5±0.25 .138	62.0±1.5 2.440	6.7±0.25 .263	0.65 22 AWG	.5	56 Min.	86±20%	52 Min.	100±20%	70 Min.	125±20%
27 - - 004112	3.5±0.25 .138	62.0±1.5 2.440	7.6±0.3 .300	0.65 22 AWG	.5	64 Min.	99±20%	60 Min.	110±20%	75 Min.	144±20%
27 - - 002112	3.5±0.25 .138	62.0±1.5 2.440	8.9±0.3 .350	0.65 22 AWG	.6	75 Min.	115±20%	70 Min.	133±20%	90 Min.	168±20%
27 - - 007112	3.5±0.25 .138	62.0±1.5 2.440	9.5±0.3 .374	0.65 22 AWG	.6	88 Min.	135±20%	77 Min.	150±20%	100 Min.	180±20%
27 - - 008112	3.5±0.25 .138	62.0±1.5 2.440	11.4±0.4 .450	0.65 22 AWG	.7	100 Min.	156±20%	93 Min.	180±20%	115 Min.	213±20%
27 - - 009112	3.5±0.25 .138	62.0±1.5 2.440	13.8±0.5 .545	0.65 22 AWG	.8	121 Min.	190±20%	114 Min.	220±20%	140 Min.	258±20%
2743012201+	9.8±0.3 .385	62.0±1.5 2.440	11.4±0.4 .449	0.8 20 AWG	4.5	—	—	154 Min.	271±20%	—	—
2743013211+	9.8±0.3 .385	62.0±1.5 2.440	14.0±0.5 .550	0.8 20 AWG	5.5	—	—	188 Min.	331±20%	—	—
2743014221+	9.8±0.3 .385	62.0±1.5 2.440	16.5±0.5 .650	0.8 20 AWG	6.5	—	—	224 Min.	391±20%	—	—

* Insert desired material in 3rd & 4th digit positions.

+ Not available taped and reeled.

Multi-Aperture Cores

Multi-aperture cores are used in balun (balance-unbalance) transformers and find wide application as broadband transformers in communication and CATV circuits.

- Available materials: 65, 61, 43 and 73. (65 material is not recommended for new designs.)
- All multi-aperture cores are supplied burnished.
- For additional technical information on the use of these cores, see section "Use of Ferrites in Broadband Transformers" found on page 31.
- Beads are controlled for impedance limits only. They are tested for impedance with a single turn through two holes, using a Hewlett Packard HP 4193A Vector Impedance Meter.

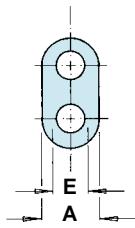


Figure 1

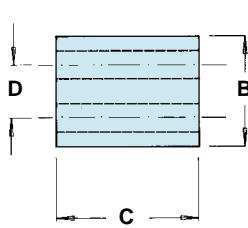


Figure 2

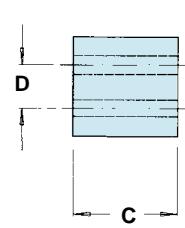
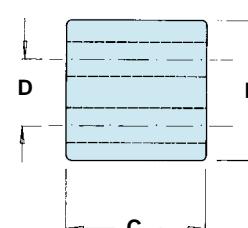


Figure 3



Dimensions (Bold numbers are in millimeters, light numbers are nominal in inches.)

Impedance (Ω)

Part Number**	Fig.	A	B	C*	D	E	Wt (g)	73		43		61		65	
								25 MHz	100 MHz	100 MHz	100 MHz	100 MHz	100 MHz		
28 - - 002302	1	2.0±0.15 .079	3.45±0.25 .136	2.35±0.25 .093	1.45±0.1 .057	0.75±0.25 .034	.1	35 Min.	35 Min.	30 Min.	30 Min.	30 Min.	30 Min.		
28 - - 002702	1	4.2 - 0.25 .160	7.0±0.25 .276	3.1±0.25 .122	2.9±0.1 .114	1.7+ 0.2 .071	.3	30 Min.	40 Min.	35 Min.	35 Min.	35 Min.	35 Min.		
28 - - 002402	1	4.2 - 0.25 .160	7.0±0.25 .276	6.2±0.25 .244	2.9±0.1 .114	1.7+ 0.2 .071	.5	60 Min.	80 Min.	70 Min.	70 Min.	70 Min.	70 Min.		
28 - - 001802	2	6.35±0.25 .250	—	6.15±0.25 .242	2.75±0.2 .108	1.1 + 0.3 .050	.8	85 Min.	105 Min.	95 Min.	95 Min.	95 Min.	95 Min.		
28 - - 001702	2	6.35±0.25 .250	—	12.0±0.35 .471	2.75±0.2 .108	1.1 + 0.3 .050	1.6	160 Min.	205 Min.	185 Min.	185 Min.	185 Min.	185 Min.		
28 - - 001502	1	7.5±0.35 .295	13.3±0.6 .525	6.6±0.25 .260	5.7±0.25 .225	3.8±0.25 .150	1.7	40 Min.	70 Min.	55 Min.	55 Min.	55 Min.	55 Min.		
28 - - 000302	1	7.5±0.35 .295	13.3±0.6 .525	10.3±0.3 .407	5.7±0.25 .225	3.8±0.25 .150	2.6	60 Min.	110 Min.	85 Min.	85 Min.	85 Min.	85 Min.		
28 - - 000102	1	7.5±0.35 .295	13.3±0.6 .525	13.4±0.3 .528	5.7±0.25 .225	3.8±0.25 .150	3.5	75 Min.	140 Min.	110 Min.	110 Min.	110 Min.	110 Min.		
28 - - 000202	1	7.5±0.35 .295	13.3±0.6 .525	14.35±0.5 .565	5.7±0.25 .225	3.8±0.25 .150	3.7	85 Min.	145 Min.	120 Min.	120 Min.	120 Min.	120 Min.		
28 - - 006802	1	7.5±0.35 .295	13.3±0.6 .525	27.0±0.75 1.062	5.7±0.25 .225	3.8±0.25 .150	7.0	155 Min.	240 Min.	225 Min.	225 Min.	225 Min.	225 Min.		
2843010402	3	9.5±0.25 .375	19.45±0.4 .765	12.7±0.5 .500	9.9±0.25 .390	4.75±0.2 .187	7.5	—	160 Min.	—	—	—	—		
2843010302	3	9.5±0.25 .375	19.45±0.4 .765	25.4±0.7 1.000	9.9±0.25 .390	4.75±0.2 .187	18	—	320 Min.	—	—	—	—		
2843009902	3	14.25±0.3 .560	28.7±0.6 1.130	28.7±0.7 .550	14.0±0.3 .550	6.35±0.15 .250	48	—	400 Min.	—	—	—	—		
2861010002	3	15.0±0.4 .590	30.2±0.6 1.190	28.7±0.7 1.130	14.0±0.3 .550	6.8±0.2 .268	46	—	—	480 Min.	—	—	—		

** Insert desired material in 3rd & 4th digit positions.

* This dimension may be modified to suit specific applications.

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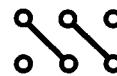
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PC Beads

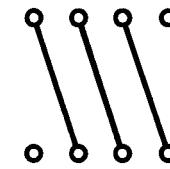
Multiple single turn printed circuit beads or multi-turn printed circuit beads are available in four sizes in Fair-Rite 44 material. The beads are supplied with tinned copper jumper wires which complete the desired winding configuration on the printed circuit board.

- Available in 44 material.
- Jumper wires are oxygen free high conductivity copper with a 95/5 tin/lead coating.
- For performance data on PC Beads, see page 59 of section "How to Choose Ferrite Components for EMI Suppression".
- Beads are controlled for impedance limits only. They are tested for impedance with a single turn through two end holes, using a Hewlett Packard HP 4193A Vector Impedance Meter.
- Wires on top of the beads are covered with a layer of an epoxy.

Typical Printed Circuit Board Layouts



2944776101
Figure 1-A 3 Turns



2944778301
Figure 3-A 4 Turns

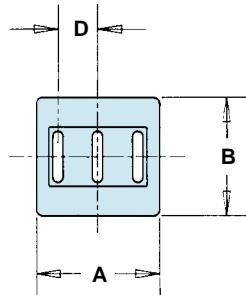


Figure 1

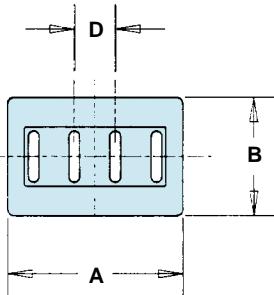
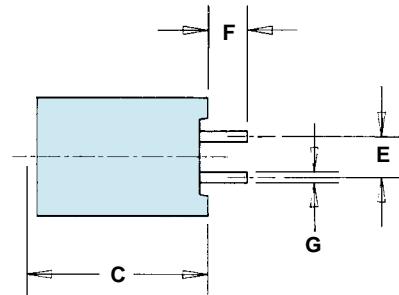


Figure 2



2944778301
Figure 3-B 2 x 2 Turns

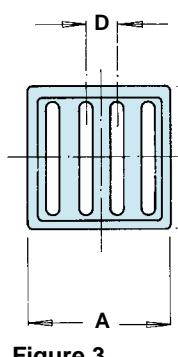


Figure 3

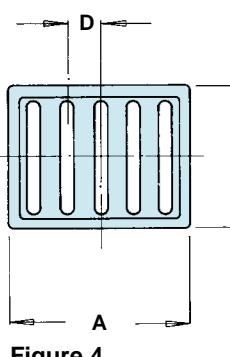
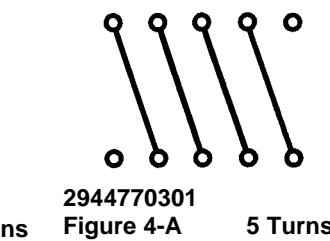


Figure 4



2944770301
Figure 4-A 5 Turns

Dimensions (**Bold** numbers are in millimeters, light numbers are nominal in inches.)

Impedance (Ω)

Part Number	Fig.	A	B	C Max.	D	E	F Min.*	G	Wt (g)	25 MHz	100 MHz
2944776101	1	8.0 - 0.35 .308	7.6 - 0.5 .290	11.4 .450	2.54±0.1 .100	2.54±0.1 .100	2.3 .090	0.65 22 AWG	2.6	150 Min.	230 Min.
2944778101	2	11.2 - 0.5 .430	5.75 - 0.5 .216	11.4 .450	2.54±0.1 .100	2.54±0.1 .100	2.3 .090	0.65 22 AWG	2.7	150 Min.	230 Min.
2944778301	3	11.2 - 0.5 .430	11.2 - 0.5 .430	11.4 .450	2.54±0.1 .100	7.6±0.2 .300	2.3 .090	0.65 22 AWG	6.0	175 Min.	270 Min.
2944770301	4	13.45±0.25 .530	11.2 - 0.5 .430	11.4 .450	2.54±0.1 .100	7.6±0.2 .300	2.3 .090	0.65 22 AWG	7.4	175 Min.	270 Min.

* Parts with a "2" as the last digit of the part number are supplied with a F Min. of 3.2mm (.125").

Wound Beads

Six and eleven hole beads, in 44 material and 61 material, are available as beads and wound with tinned copper wire in several winding configurations.

- Available materials: 44 and 61.
- Parts with a "1" as the last digit of the part number are supplied bulk packed. Parts 29 - - 666651 and 29 - - 666631 can be supplied radially taped and reeled per EIA Standard 468-B. This packing method will change the last digit of the part number to a "4".
- Wire used for winding is oxygen free high conductivity copper with a tin plating.
- For performance data on Wound Beads, see page 58 of section "How to Choose Ferrite Components for EMI Suppression".
- Beads are controlled for impedance limits only. They are tested for impedance using a Hewlett Packard HP 4193A Vector Impedance Meter for beads in 44 material and the HP 4191A RF Impedance Analyzer for 61 material beads.
- The Expanded Bead-on-Lead EMI Suppressor Kit (part number 0199000010) is available for prototype evaluation. See page 84.

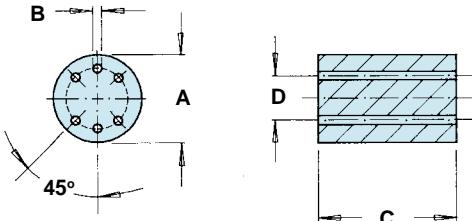


Figure 1

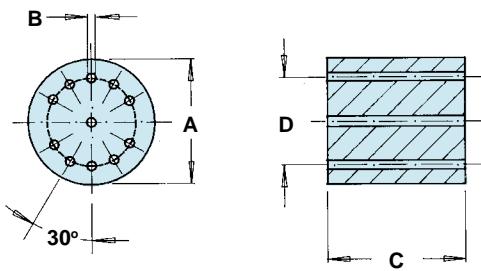


Figure 2

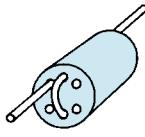


Figure 1-1

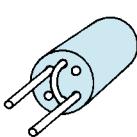


Figure 1-2

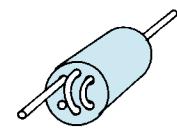


Figure 1-3

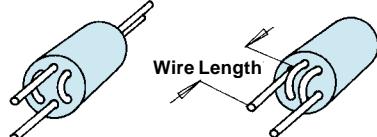


Figure 1-4

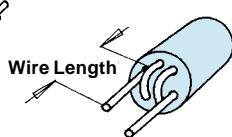


Figure 1-5



Figure 2-1

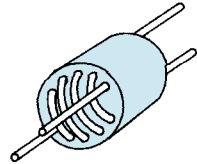


Figure 2-2

Dimensions (Bold numbers are in millimeters, light numbers are nominal in inches.)

Impedance (Ω)

Part Number*	Fig.	A	B	C	D_{Ref}	Wt (g)	44			61		
							10 MHz	50 MHz	100 MHz	50 MHz	100 MHz	200 MHz
26 - - 666611 ^①	1	6.0±0.25 .236	0.75±0.15 .032	10.0±0.25 .394	3.5 .138	1.2	170 Min.	320 Min.	375 Min.	250 Min.	400 Min.	325 Min.
2644777711 ^②	2	10.0±0.25 .394	0.9±0.15 .038	10.0±0.25 .394	7.5 .295	3.3	300 Min.	725 Min.	400 Min.	—	—	—

① Tested with 1½ Turns ② Tested with 2½ turns

Part Number*	Fig.	Turns	Wire Size	Wire Length	Wt (g)	44			61		
						10 MHz	50 MHz	100 MHz	50 MHz	100 MHz	200 MHz
29 - - 66661	1-1	1½	0.53 24 AWG	38.0±3.0 1.500	1.3	170 Min.	320 Min.	375 Min.	250 Min.	400 Min.	325 Min.
29 - - 666651	1-2	2	0.53 24 AWG	38.0±3.0 1.500	1.3	240 Min.	520 Min.	480 Min.	425 Min.	600 Min.	300 Min.
29 - - 666671	1-3	2½	0.53 24 AWG	38.0±3.0 1.500	1.4	320 Min.	680 Min.	580 Min.	550 Min.	675 Min.	275 Min.
29 - - 666681	1-4	2 x 1½	0.53 24 AWG	38.0±3.0 1.500	1.4	170 Min.	320 Min.	375 Min.	250 Min.	400 Min.	325 Min.
29 - - 666631	1-5	3	0.53 24 AWG	38.0±3.0 1.500	1.4	400 Min.	800 Min.	550 Min.	650 Min.	625 Min.	250 Min.
2944777741	2-1	4½	0.65 22 AWG	38.0±3.0 1.500	3.8	650 Min.	1000 Min.	400 Min.	—	—	—
2944777721	2-2	2 x 2½	0.65 22 AWG	(3)	3.9	300 Min.	725 Min.	400 Min.	—	—	—

* Insert desired material in 3rd & 4th digit positions.

(3) Wire length of one winding is **38.0±3.0** (1.500). Wire length of second winding is **28.5±3.0** (1.125)

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Tile Absorber

Ferrite Tile Absorber

for EMC Test Chamber
Applications from 30-1500 MHz



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Fair-Rite Products Corp.

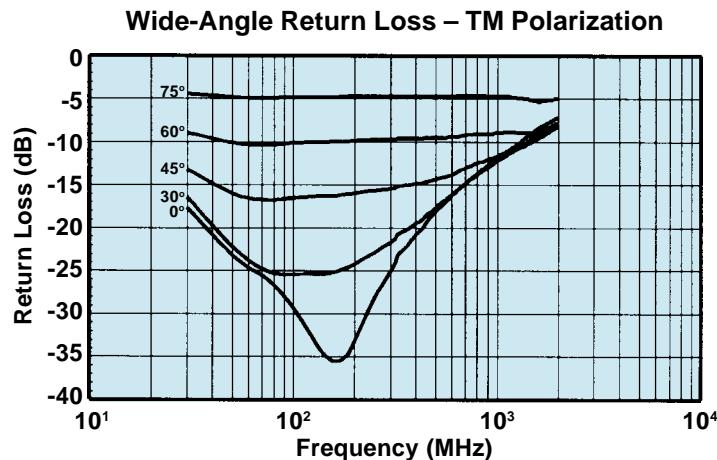
Tile Absorber

Fair-Rite's 42 material tile absorbers provide plane wave electromagnetic attenuation from 30 - 1500 MHz for use in anechoic chambers for radiated emissions and immunity measurements.

Fair-Rite's tile absorbers were developed using our 42 nickel zinc ferrite material which has been optimized to produce exceptionally consistent, broadband absorption at frequencies down to 26 MHz. The tiles are immune to fire, humidity and chemicals, providing a reliable and compact solution for attenuating plane wave reflections in shielded enclosures.

Physical Characteristics of 42 Material

Specific Gravity	5.2
Young's Modulus	1.8×10^4 kgf/mm ²
Tensile Strength	4.9 kgf/mm ²
Compressive Strength	42 kgf/mm ²
Flexural Strength	6 kgf/mm ²
Vickers Hardness	740
Coeff. of Thermal Expansion	9 $10^{-6}/^{\circ}\text{C}$
Initial Permeability (relative)	2100 μ_r
Relative Permittivity	14 ϵ_r
Resistivity	5×10^6 ohm-cm
Curie Temperature	> 95 $^{\circ}\text{C}$
Composition	Nickel-Zinc Ferrite
Power Handling (CW)	400 V/m

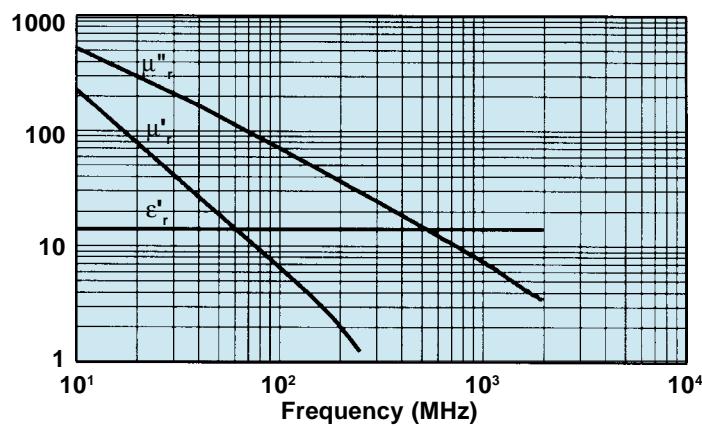


TE Polarization similar. Normal incidence return loss shown above (0°)

Normal Incidence Return Loss (dB)

	Freq (MHz)						
Part Number	30	100	200	400	600	1000	1500
3642011601	-18	-25	-30	-25	-20	-12	-9

Tile Material Properties Relative Permeability (μ_r) & Permittivity (ϵ_r)



Tile Absorber

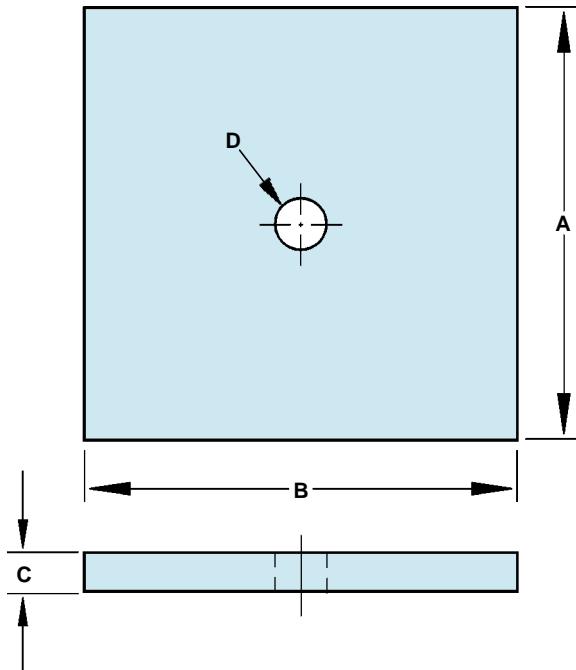
- Tiles are surface ground on all sides to precise mechanical tolerances minimizing gaps between adjacent tiles to ensure maximum low-frequency performance.
- For additional technical information on absorber tile applications, see section "Ferrite Tile Absorber for EMC Test Chamber Applications" found on page 62.
- Panels and individual tiles may be mounted to walls with screws, epoxy or contact adhesive depending on conditions.

Tiles

Dimensions (**Bold numbers** are in millimeters, light numbers are nominal in inches.)

Part Number	A	B	C*	D	Wt (g)
3642011601	100 ±0.13 3.937	100 ±0.13 3.937	6.3 ±0.13 .248	10 ±0.3 .394	324

* Other custom thicknesses available from **5.0** to **6.7mm**



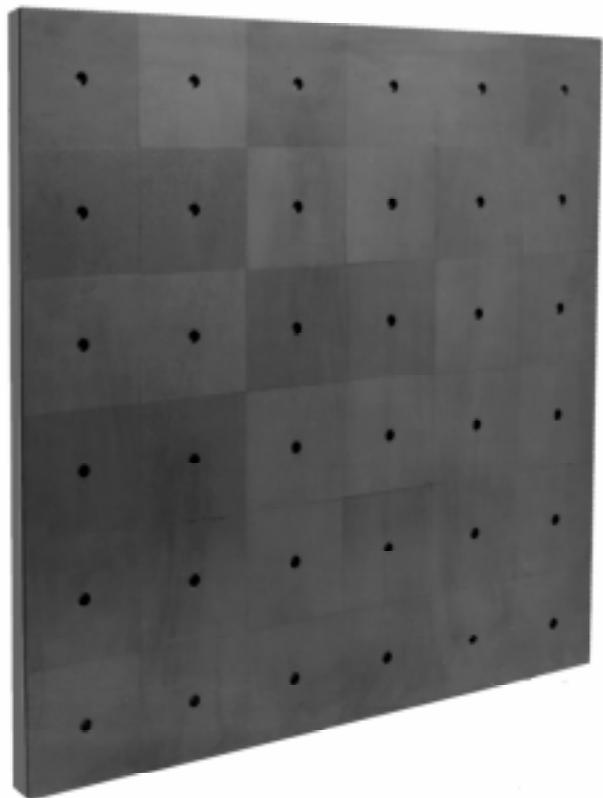
Panels

Dimensions (**Bold numbers** are in millimeters, light numbers are in inches.)

Part Number	A	B	C	Wt (kg)
3742011901	600 23.62	600 23.62	16.8 .66	17.7

Each panel consists of:

36 Ferrite Tiles epoxy bonded to **9mm** (.35") particle board faced on both sides with 26 ga (**0.46mm**) zinc coated steel.



Slugs

The simplest form of Fair-Rite pressed cores, used extensively for inductive devices when inductance tolerances of $\pm 10\%$ are permissible.

Applications include coils for differential input filters, chokes for SCR and triac circuits, inductors in audio cross-over networks and pulse transformers.

- Available materials: 61, 33 and 77.
- The "A" dimension can be centerless ground to tighter tolerances.
- Slugs 4277142009 through 4277453509 are used in the assembled bobbins, listed on page 110, figure 4. These slugs have a **0.6mm (.025")** max. chamfer on the outside corners.
- For information on slug permeability vs. slug dimensions, see page 24.

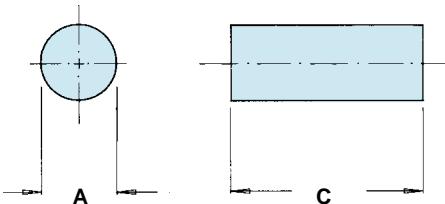


Figure 1

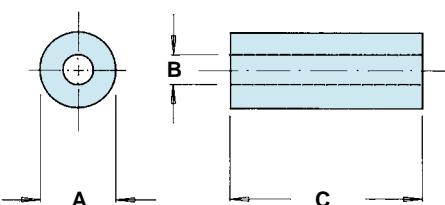


Figure 2

Dimensions (**Bold numbers** are in millimeters, light numbers are nominal in inches.)

Part Number**	Fig.	A	B	C*	Available Materials			Wt (g)
					61	33	77	
40 - - 032221	1	0.95±0.025 .037	—	7.9±0.3 .312	—	✓	✓	.08
4033129021	1	3.25 - 0.25 .125	—	12.7±0.4 .500	—	✓	—	.5
4033128021	1	3.25 - 0.25 .125	—	19.05±0.76 .750	—	✓	—	.8
4033122011	1	3.25 - 0.25 .125	—	25.4±0.75 1.000	—	✓	—	1.1
4077172011	1	4.6 - 0.3 .175	—	22.2±0.76 .875	—	—	✓	1.9
4077272011	1	6.35±0.25 .250	—	19.05±0.76 .750	—	—	✓	2.7
40 - - 287011	1	6.35±0.25 .250	—	22.1±0.7 .870	✓	✓	✓	3.5
40 - - 276011	1	6.35±0.25 .250	—	25.4±0.7 1.000	✓	✓	✓	3.8
40 - - 292011	1	6.35±0.25 .250	—	28.6±0.7 1.125	✓	✓	✓	4.4
40 - - 296011	1	6.35±0.25 .250	—	31.75±0.75 1.250	✓	✓	✓	4.8
40 - - 266011	1	6.35±0.25 .250	—	38.1±0.75 1.500	✓	✓	✓	5.9
4077312911	1	8.0±0.35 .315	—	38.1±0.75 1.500	—	—	✓	9.1
4077374711	1	9.45±0.2 .372	—	31.75±0.75 1.250	—	—	✓	11
4077375411	1	9.45±0.2 .372	—	41.3±0.8 1.625	—	—	✓	14
4077375211	1	9.45±0.2 .372	—	50.8±1.0 2.000	—	—	✓	18
4077485111	1	12.3±0.4 .485	—	31.75±0.75 1.250	—	—	✓	19
4077484611	1	12.3±0.4 .485	—	41.3±0.8 1.625	—	—	✓	24
4277142009	2	9.0±0.3 .354	3.2±0.1 .126	13.5±0.3 .532	—	—	✓	3.7
4277182009	2	11.0±0.3 .433	3.2±0.1 .126	13.5±0.3 .532	—	—	✓	5.7
4277182209	2	11.0±0.3 .433	3.2±0.1 .126	15.5±0.35 .610	—	—	✓	6.6
4277242009	2	13.0±0.3 .512	3.2±0.1 .126	13.5±0.3 .532	—	—	✓	8.3
4277242409	2	13.0±0.3 .512	3.2±0.1 .126	17.5±0.4 .690	—	—	✓	11
4277282009	2	17.0±0.4 .670	4.2±0.15 .165	13.5±0.3 .532	—	—	✓	14
4277282509	2	17.0±0.4 .670	4.2±0.15 .165	18.95±0.45 .746	—	—	✓	19
4277352509	2	21.0±0.5 .825	6.9±0.4 .272	18.95±0.45 .746	—	—	✓	28
4277353509	2	21.0±0.5 .825	6.9±0.4 .272	29.0±0.6 1.140	—	—	✓	43
4277453509	2	27.0±0.5 1.063	9.0±0.3 .354	27.0±0.6 1.064	—	—	✓	66

* This dimension may be modified to suit specific applications.

** Insert desired material in 3rd & 4th digit positions.

✓ Denotes available standard slugs.

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Discs

Discs can be used with certain slugs to increase inductance and improve shielding.

- Available in 77 material.
- These discs are used in the assembled bobbins, listed on page 110, figure 4.
- Discs are burnished to facilitate bobbin winding.

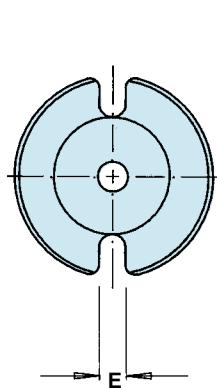


Figure 1

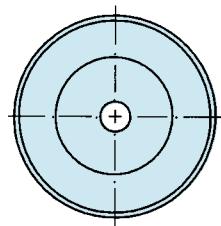
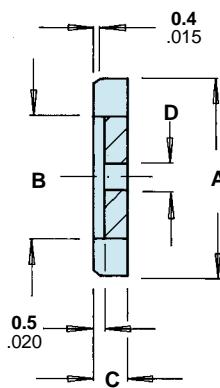
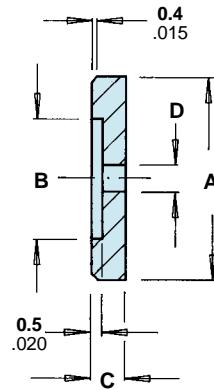


Figure 2



Dimensions (Bold numbers are in millimeters, light numbers are nominal in inches.)

Part Number	Fig.	A	B	C	D	E	Wt (g)
5477140009	1	14.0±0.35 .551	8.8±0.25 .352	3.6±0.3 .148	4.6±0.3 .187	2.0±0.3 .079	2.4
5477140007	2	14.0±0.35 .551	8.8±0.25 .352	3.6±0.3 .148	4.6±0.3 .187	—	2.4
5477180009	1	18.0±0.45 .709	10.8±0.25 .430	3.6±0.3 .148	4.6±0.3 .187	2.5±0.3 .098	3.8
5477180007	2	18.0±0.45 .709	10.8±0.25 .430	3.6±0.3 .148	4.6±0.3 .187	—	3.9
5477240009	1	24.0±0.6 .945	12.8±0.3 .510	3.6±0.3 .148	4.6±0.3 .187	3.0±0.3 .118	6.9
5477240007	2	24.0±0.6 .945	12.8±0.3 .510	3.6±0.3 .148	4.6±0.3 .187	—	7.6
5477280009	1	28.0±0.7 1.102	16.65±0.3 .661	3.6±0.3 .148	6.0±0.25 .236	3.0±0.3 .118	9.7
5477280007	2	28.0±0.7 1.102	16.65±0.3 .661	3.6±0.3 .148	6.0±0.25 .236	—	10
5477350009	1	35.0±0.9 1.381	20.65±0.3 .819	3.4±0.25 .138	8.3±0.3 .327	3.0±0.3 .118	14
5477350007	2	35.0±0.9 1.381	20.65±0.3 .819	3.4±0.25 .138	8.3±0.3 .327	—	15
5477450009	1	45.0±1.0 1.771	26.5±0.4 1.052	4.4±0.25 .177	9.0±0.3 .354	3.6±0.3 .142	31
5477450007	2	45.0±1.0 1.771	26.5±0.4 1.052	4.4±0.25 .177	9.0±0.3 .354	—	31

Pot Cores

The pot core has found wide application in all types of inductive devices. The core configuration provides a high degree of self-shielding. It also facilitates gapping to enhance its utility for a variety of magnetic designs.

- Available materials: 77 and 78.
- Part number is for a single core.
- Pot cores in 78 material can be supplied with the center post gapped to a mechanical dimension.
- Pot cores in 78 material can also be gapped to an A_L value. These cores will be supplied as sets.
- A_L value is measured at 1kHz, <10 gauss.
- See section "The Effect of Direct Current on the Inductance of a Ferrite Core" on page 29 for curves of A_L vs. gap length.
- The pot cores shown in figure 1 are in conformance with IEC 133.

Dimensions (**Bold numbers** are in millimeters, light numbers are nominal in inches.)

Part Number*	Fig.	A	B	C	D	E	F	G	H	J Min.
56 - - 140821	1	14.05±0.25 .553	11.8±0.2 .465	5.9±0.1 .232	3.1±0.1 .122	4.25 - 0.15 .164	2.9±0.1 .114	2.9±0.4 .122	9.5±0.25 .374	0.2 .008
56 - - 181121	1	18.0±0.4 .709	15.15±0.25 .596	7.45±0.15 .293	3.1±0.1 .122	5.35 - 0.15 .208	3.7±0.1 .146	3.85±0.6 .152	12.3±0.3 .484	0.3 .012
56 - - 221321	1	21.6±0.4 .850	18.2±0.3 .717	9.25±0.15 .364	4.55±0.15 .179	6.7±0.1 .264	4.7±0.1 .185	3.1±0.6 .122	14.9±0.35 .587	0.4 .016
56 - - 261621	1	25.5±0.5 1.004	21.6±0.4 .850	11.3±0.2 .445	5.55±0.15 .218	8.05±0.1 .317	5.6±0.1 .220	3.6±0.6 .142	18.15±0.4 .715	0.5 .020
56 - - 301921	1	30.0±0.5 1.181	25.4±0.4 1.000	13.3±0.2 .524	5.55±0.15 .218	9.4±0.1 .370	6.6±0.1 .260	4.2±0.6 .165	21.5±0.5 .846	0.6 .024
56 - - 362221	1	35.6±0.6 1.402	30.4±0.5 1.197	15.9±0.3 .626	5.55±0.15 .218	10.85±0.15 .427	7.45±0.15 .293	5.1±0.5 .201	26.0±0.5 1.024	0.6 .024
55 - - 000721	2	22.85±0.45 .900	18.3±0.35 .720	9.7±0.2 .382	5.1±0.15 .200	9.2 - 0.35 .355	7.25±0.2 .285	—	—	—
55 - - 000821	3	22.85±0.45 .900	18.3±0.35 .720	9.7±0.2 .382	5.1±0.15 .200	9.2 - 0.35 .355	7.25±0.2 .285	13.0 Min .511	15.25±0.25 .600	—
55 - - 000921	2	22.85±0.45 .900	18.3±0.35 .720	9.7±0.2 .382	5.1±0.15 .200	5.65 - 0.25 .218	3.75±0.1 .148	—	—	—
55 - - 001021	3	22.85±0.45 .900	18.3±0.35 .720	9.7±0.2 .382	5.1±0.15 .200	5.65 - 0.25 .218	3.75±0.1 .148	13.0 Min .511	15.25±0.25 .600	—

* Insert desired material in 3rd & 4th digit positions.

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Pot Cores

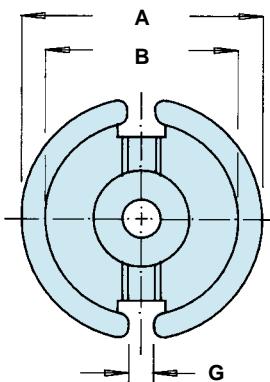


Figure 1

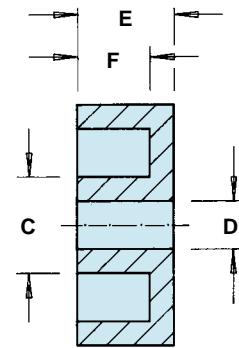
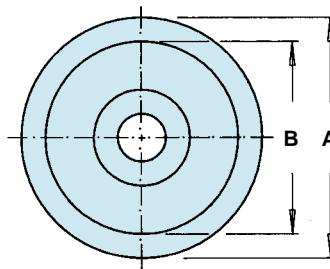
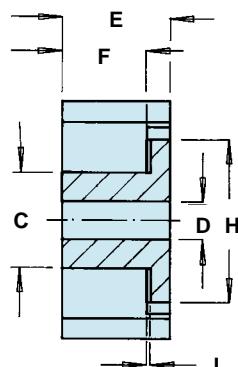


Figure 2

Symbols	Definitions
$\Sigma l/A$	Core constant
l_e	Effective path length
A_e	Effective cross-sectional area
V_e	Effective core volume
A_L	Inductance factor ($\frac{L}{N^2}$)

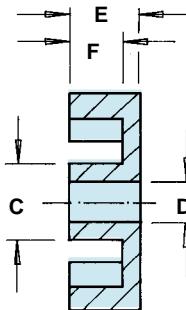
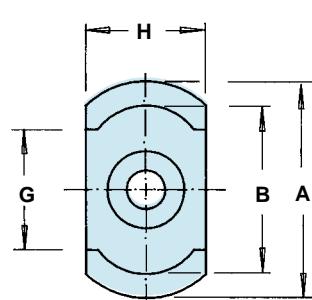


Figure 3

Magnetic Parameters

Part Number*	$\Sigma l/A(\text{cm}^{-1})$	$l_e(\text{cm})$	$A_e(\text{cm}^2)$	$V_e(\text{cm}^3)$	$A_{\min}(\text{cm}^2)$	Wt (g)	$A_L(\text{nH})$	
							77	78
56 - - 140821	8.0	2.00	.250	.50	.197	1.9	1450 Min.	1575 Min.
56 - - 181121	6.0	2.59	.43	1.12	.360	4.7	2150 Min.	2350 Min.
56 - - 221321	5.0	3.16	.63	2.00	.51	7.2	2725 Min.	3000 Min.
56 - - 261621	4.0	3.76	.93	3.46	.76	12	3525 Min.	3900 Min.
56 - - 301921	3.30	4.5	1.36	6.1	1.14	19	4425 Min.	4900 Min.
56 - - 362221	2.58	5.2	2.02	10.6	1.74	34	5875 Min.	6550 Min.
55 - - 000721	6.75	4.3	.63	2.70	.53	11	2200 Min.	2475 Min.
55 - - 000821						7.6		
55 - - 000921	4.54	2.87	.63	1.80	.53	7.3	2925 Min.	5350 Min.
55 - - 001021						5.2		

* Insert desired material in 3rd & 4th digit positions.

Toroids

The ring configuration provides the ultimate in the utilization of the ferrite material properties. Power input filters, ground-fault interrupters and a variety of pulse and matching transformers are only a few of the applications for this core type.

- Available materials: 61, 43, 77, 75, 76, and 85.
- All toroidal cores are supplied burnished to remove sharp edges.
- Additional toroidal cores in 43 material for EMI applications are listed in the shield bead section.
- Toroids in 85 material are specified to a squareness ratio and not specified to an A_L value.
- Toroids are tested for A_L values at <10 gauss at these frequencies:

43-75-77 material at 100 kHz,
76 material 10 kHz,
61 material 1 MHz.

- Toroids with an outside diameter of **9.5mm** (.375") or larger can be supplied with a uniform coating of a white epoxy enamel. This coating will increase "A" and "C" dimensions and decrease the "B" dimension a maximum of **.25mm** (.010"). The 9th digit of white epoxy enamel coated toroids is a "2".
- Epoxy coated toroidal cores can withstand a minimum breakdown voltage of 1000VRms, uniformly applied across the "C" dimension of the core.
- Fair-Rite has the in-house capability to coat small ferrite parts with Parylene C. Toroids with a diameter of **9.5mm** (.375") or smaller can be supplied Parylene coated. This coating will increase "A" and "C" dimensions and decrease the "B" dimension a maximum of **.038mm** (.0015"). The 9th digit of Parylene coated toroids is a "1". See page 6 for material characteristics of Parylene C.

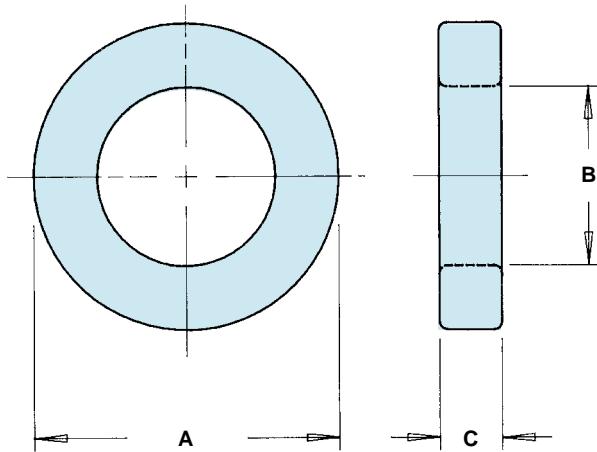
Dimensions (**Bold** numbers are in millimeters, light numbers are nominal in inches.)

Part Number**	A	B	C*	Wt (g)
59 - - 000801	3.95±0.15 .155	2.15±0.15 .088	1.35 - 0.15 .050	.05
59 - - 002101	4.95 - 0.25 .190	2.2±0.15 .090	1.35 - 0.15 .050	.09
59 - - 000101	5.95 - 0.25 .230	3.05±0.1 .120	1.65 - 0.25 .060	.14
59 - - 000201	9.5±0.2 .375	4.75±0.15 .187	3.3 - 0.25 .125	.83

** Insert desired material in 3rd and 4th digit positions.

* This dimension may be modified to suit specific applications.

Toroids


Symbols Definitions

$\Sigma l/A$	Core constant
l_e	Effective path length
A_e	Effective cross-sectional area
V_e	Effective core volume
A_L	Inductance factor ($\frac{L}{N^2}$)

Magnetic Parameters

Part Number**	$\Sigma l/A(\text{cm}^{-1})$	$l_e(\text{cm})$	$A_e(\text{cm}^2)$	$V_e(\text{cm}^3)$	$A_L(\text{nH}) \pm 20\%$					
					61	43	77	75	76 ^{\$}	85
59 - - 000801	87.6	0.92	0.011	0.0097	—	120	285	715	1430	—
59 - - 002101	69.2	1.04	0.015	0.0157	—	160	360	900	1800	—
59 - - 000101	63.8	1.30	0.020	0.027	25	165	390	975	1950	—
59 - - 000201	28.6	2.07	0.072	0.15	55	375	880	2200	4400	✓

** Insert desired material in 3rd and 4th digit positions.

^{\$} A_L tolerance $\pm 30\%$

✓ Denotes available standard toroids in 85 material.

Toroids

Dimensions (**Bold numbers** are in millimeters, light numbers are nominal in inches.)

Part Number**	A	B	C*	Wt (g)
59 - - 000301	12.7±0.25 .500	7.15±0.2 .281	4.9 - 0.25 .188	2.0
59 - - 001101	12.7±0.25 .500	7.9±0.2 .312	6.35±0.25 .250	2.4
59 - - 001901	12.7±0.25 .500	7.9±0.2 .312	12.7±0.35 .500	4.7
59 - - 005101	16.0±0.4 .630	9.6±0.3 .378	4.75 - 0.25 .182	2.8
59 - - 004901	16.0±0.4 .630	9.6±0.3 .378	6.35±0.25 .250	4.0
59 - - 000601	21.0±0.35 .825	13.2±0.3 .520	6.35±0.25 .250	6.4
59 - - 000501	21.0±0.35 .825	13.2±0.3 .520	11.9±0.4 .468	12
59 - - 001801	22.1±0.4 .870	13.7±0.3 .540	6.35±0.25 .250	7.2
59 - - 007601	22.1±0.4 .870	13.7±0.3 .540	12.7±0.45 .500	15
59 - - 001301	25.4±0.6 1.000	15.5±0.5 .610	6.35±0.25 .250	9.6
59 - - 001401	25.4±0.6 1.000	15.5±0.5 .610	8.15±0.3 .320	12
59 - - 006401	25.4±0.6 1.000	15.5±0.5 .610	12.7±0.5 .500	18
59 - - 001001	29.0±0.65 1.142	19.0±0.5 .748	7.5±0.25 .295	13
59 - - 001201	29.0±0.65 1.142	19.0±0.5 .748	13.85±0.3 .545	26
59 - - 001601	31.1±0.75 1.225	19.05±0.5 .750	7.9±0.3 .312	18
59 - - 001701	31.75±0.75 1.250	19.05±0.5 .750	9.5±0.3 .375	23
59 - - 002701	35.55±0.75 1.400	23.0±0.55 .900	12.7±0.5 .500	33
59 - - 003801	61.0±1.3 2.400	35.55±0.85 1.400	12.7±0.5 .500	106
59 - - 011101	73.65±1.5 2.900	38.85±0.75 1.530	12.7±0.4 .500	188

** Insert desired material in 3rd and 4th digit positions.

* This dimension may be modified to suit specific applications.

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Toroids

Symbols	Definitions
$\Sigma l/A$	Core constant
l_e	Effective path length
A_e	Effective cross-sectional area
V_e	Effective core volume
A_L	Inductance factor ($\frac{L}{N^2}$)

Magnetic Parameters

Part Number**	$\Sigma l/A(\text{cm}^{-1})$	$l_e(\text{cm})$	$A_e(\text{cm}^2)$	$V_e(\text{cm}^3)$	$A_L(\text{nH}) \pm 20\%$				
					61	43	77	75	85
59 - - 000301	22.9	2.95	0.129	0.38	69	470	1100	2725	✓
59 - - 001101	20.8	3.12	0.150	0.47	75	510	1200	3000	✓
59 - - 001901	10.4	3.12	0.299	0.93	150	1025	2400	6000	✓
59 - - 005101	26.6	3.85	0.145	0.56	—	400	940	2350	✓
59 - - 004901	19.4	3.85	0.199	0.77	80	550	1300	3225	✓
59 - - 000601	21.3	5.2	0.243	1.26	75	500	1175	2950	✓
59 - - 000501	11.4	5.2	0.46	2.36	135	940	2200	5500	✓
59 - - 001801	20.7	5.4	0.262	1.42	75	510	1200	3025	✓
59 - - 007601	10.3	5.4	0.52	2.83	—	1025	2425	6100	✓
59 - - 001301	20.0	6.2	0.308	1.90	—	530	1250	—	✓
59 - - 001401	15.1	6.2	0.41	2.52	—	700	1600	—	✓
59 - - 006401	10.0	6.2	0.62	3.80	—	1060	2500	—	✓
59 - - 001001	19.8	7.3	0.37	2.70	80	540	1275	—	—
59 - - 001201	10.7	7.3	0.68	5.0	145	1000	2350	—	—
59 - - 001601	16.2	7.6	0.47	3.53	—	660	1550	—	—
59 - - 001701	12.9	7.6	0.59	4.5	120	825	1950	—	—
59 - - 002701	11.2	8.9	0.79	7.0	140	950	2250	—	—
59 - - 003801	9.2	14.5	1.58	22.8	170	1160	2725	—	—
59 - - 011101	7.8	16.7	2.15	35.9	—	1375	3225	—	—

** Insert desired material in 3rd and 4th digit positions.

✓ Denotes available standard toroids in 85 material.

EP Cores

The EP core design reduces the effect of residual air gap upon the effective permeability of the core, hence it minimizes coil volume for a given inductance.

Also, the core geometry provides a high degree of isolation from adjacent components. EP cores are advantageously used in low power devices, matching and broadband transformers.

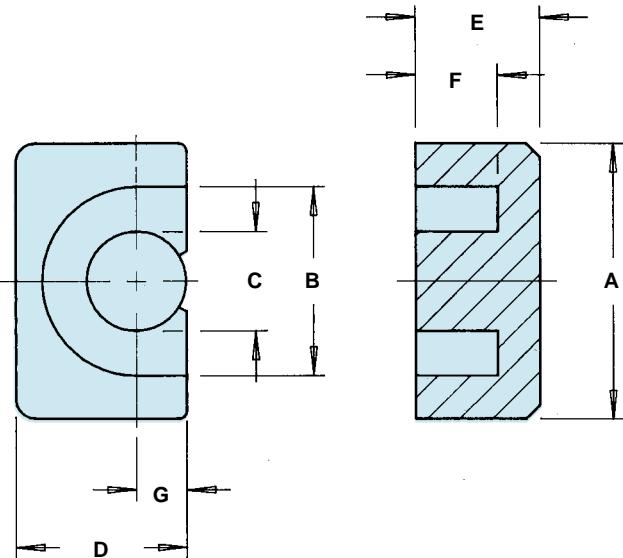
- Available materials: 77, 78, and 75.
- Part number is for a single core.
- EP cores can be supplied with the center post gapped to a mechanical dimension.
- EP cores can also be gapped to an A_L value. These cores will be supplied as sets.
- A_L value is measured at 1kHz, <10 gauss.
- See section "The Effect of Direct Current on the Inductance of a Ferrite Core" on page 29 for curves of A_L vs. gap length.
- The EP cores are in conformance with IEC 1596.

Dimensions (**Bold numbers** are in millimeters, light numbers are nominal in inches.)

Part Number*	A	B	C	D	E	F	G Max.	Wt (g)
65 - - 070721	9.2±0.2 .362	7.4±0.2 .291	3.3±0.1 .130	6.35±0.15 .250	3.7±0.05 .146	2.6±0.1 .102	1.8 .071	.8
65 - - 101021	11.5±0.3 .453	9.4±0.2 .370	3.3±0.15 .130	7.65±0.2 .301	5.1±0.1 .201	3.7±0.1 .146	1.95 .077	1.5
65 - - 131321	12.5±0.3 .492	10.0±0.3 .394	4.35±0.15 .171	8.8±0.2 .346	6.5 - 0.15 .253	4.6±0.1 .181	2.5 .088	2.5
65 - - 171721	18.0±0.5 .709	12.0±0.4 .472	5.85 - 0.35 .223	11.0±0.25 .433	8.4±0.1 .331	5.65±0.15 .222	3.45 .136	6.4
65 - - 202021	24.0±0.5 .945	16.5±0.4 .650	8.75±0.25 .344	14.95±0.35 .589	10.7±0.1 .421	7.15±0.15 .281	4.7 .185	15

* Insert desired material in 3rd & 4th digit positions.

EP Cores


Symbols Definitions

$\Sigma l/A$	Core constant
l_e	Effective path length
A_e	Effective cross-sectional area
V_e	Effective core volume
A_L	Inductance factor ($\frac{l}{N^2}$)

Magnetic Parameters

Part Number*	$\Sigma l/A(\text{cm}^{-1})$	$l_e(\text{cm})$	$A_e(\text{cm}^2)$	$V_e(\text{cm}^3)$	$A_{\min}(\text{cm}^2)$	$A_L(\text{nH})$		
						77	78	75
65 - - 070721	15.2	1.57	0.103	0.163	0.085	825 Min.	825 Min.	1900 Min.
65 - - 101021	17.0	1.93	0.113	0.217	0.085	790 Min.	790 Min.	1900 Min.
65 - - 131321	12.4	2.42	0.195	0.47	0.148	1200 Min.	1200 Min.	2800 Min.
65 - - 171721	8.4	2.85	0.339	0.97	0.252	1875 Min.	1875 Min.	4400 Min.
65 - - 202021	5.1	4.0	0.78	3.12	0.60	3150 Min.	3150 Min.	7200 Min.

* Insert desired material in 3rd & 4th digit positions.

PQ Cores

The PQ core was developed for use in power applications. The large core surface area for the volume of the core aids in heat dissipation.

These cores are employed both in filter and transformer designs in switched-mode power supplies.

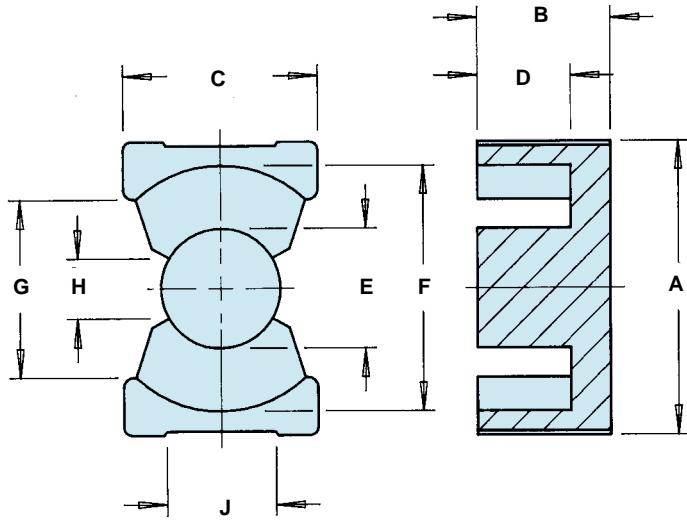
- Available materials: 77 and 78.
- Part number is for a single core.
- PQ cores can be supplied with the center post gapped to a mechanical dimension.
- PQ cores can also be gapped to an A_g value. These cores will be supplied as sets.
- A_g value is measured at 1kHz, <10 gauss.
- See section "The Effect of Direct Current on the Inductance of a Ferrite Core" on page 29 for curves of A_g vs. gap length.

Dimensions (**Bold numbers** are in millimeters, light numbers are nominal in inches.)

Part Number*	A	B	C	D	E	F	G Min.	H Min.	J
66 - - 201621	21.25±0.4 .837	8.1±0.1 .319	14.0±0.4 .551	5.0±0.3 .203	8.8±0.2 .346	18.0±0.4 .709	12.0 .472	4.0 .158	8.4-0.5 .321
66 - - 202021	21.25±0.4 .837	10.1±0.1 .398	14.0±0.4 .551	7.0±0.3 .281	8.8±0.2 .346	18.0±0.4 .709	12.0 .472	4.0 .158	8.4-0.5 .321
66 - - 262021	27.25±0.45 1.073	10.2-0.25 .397	19.0±0.45 .748	5.6±0.3 .226	12.0±0.2 .472	22.5±0.45 .886	15.5 .610	6.0 .236	11.0-0.5 .423
66 - - 262521	27.25±0.45 1.073	12.5-0.25 .487	19.0±0.45 .748	7.9±0.3 .317	12.0±0.2 .472	22.5±0.45 .886	15.5 .610	6.0 .236	11.0-0.5 .423
6677322021	33.0±0.5 1.300	10.4-0.25 .406	22.0±0.5 .866	5.6±0.3 .226	13.45±0.25 .530	27.5±0.5 1.083	19.0 .748	5.5 .216	12.8-0.5 .494
6677323021	33.0±0.5 1.300	15.3-0.25 .597	22.0±0.5 .866	10.5±0.3 .419	13.45±0.25 .530	27.5±0.5 1.083	19.0 .748	5.5 .216	12.8-0.5 .494
6677353521	36.1±0.6 1.422	17.5-0.25 .684	26.0±0.5 1.024	12.35±0.3 .492	14.35±0.25 .565	32.0±0.5 1.260	23.5 .925	5.95 .234	13.1-0.5 .506
6677404021	41.5±0.9 1.633	20.0-0.25 .782	28.0±0.6 1.102	14.6±0.3 .581	14.9±0.3 .587	37.0±0.6 1.457	28.0 1.102	6.35 .250	13.6±0.25 .535

* Insert desired material in 3rd & 4th digit positions.

PQ Cores


Symbols Definitions

$\Sigma l/A$	Core constant
l_e	Effective path length
A_e	Effective cross-sectional area
V_e	Effective core volume
A_L	Inductance factor ($\frac{L}{N^2}$)

Magnetic Parameters

Part Number*	$\Sigma l/A(\text{cm}^{-1})$	$l_e(\text{cm})$	$A_e(\text{cm}^2)$	$V_e(\text{cm}^3)$	$A_{\min}(\text{cm}^2)$	Wt (g)	$A_L(\text{nH})$	
							77	78
66 - - 201621	6.03	3.74	0.62	2.30	0.58	7.2	2550 Min.	2850 Min.
66 - - 202021	7.42	4.6	0.62	2.82	0.58	8.3	2175 Min.	2360 Min.
66 - - 262021	3.87	4.6	1.19	5.5	1.09	16	4050 Min.	4575 Min.
66 - - 262521	4.71	5.6	1.18	6.6	1.09	19	3450 Min.	3900 Min.
6677322021	3.29	5.6	1.70	9.5	1.37	22	5025 Min.	—
6677323021	4.66	7.5	1.61	12.7	1.37	30	3550 Min.	—
6677353521	4.49	8.8	1.96	17.2	1.56	37	3600 Min.	—
6677404021	5.07	10.2	2.01	20.5	1.67	50	3225 Min.	—

* Insert desired material in 3rd & 4th digit positions.

U Cores

The U core offers an economical core design with a nearly uniform cross-sectional area.

In a power ferrite material they are frequently used in output chokes, power input filters and transformers for switched-mode power supplies and HF fluorescent ballasts.

- Available materials: 77 and 78.
- Part number is for a single core.
- These U cores have the same minimum cross-sectional area as the listed effective cross-sectional area.
- A_L value is measured at 1kHz, < 10 gauss.

Dimensions (**Bold numbers** are in millimeters, light numbers are nominal in inches.)

Part Number	Fig.	A	B	C	D Min.	E Min.	F	Wt (g)
9077002002	1	8.9 - 0.5 .340	4.45+0.25 .180	4.05±0.2 .160	1.3 .051	2.3 .090	—	.7
9077026002+	1	25.4±0.75 1.000	12.6+0.25 .500	6.6 - 0.5 .250	6.2 .244	12.45 .490	—	9.0
9077025002+	1	25.4±0.75 1.000	15.75+0.25 .625	6.6 - 0.5 .250	9.4 .370	12.45 .490	—	9.0
9077024002+	1	25.4±0.75 1.000	18.9+0.25 .750	6.6 - 0.5 .250	12.55 .494	12.45 .490	—	10
9277023002	2	26.5±0.7 .045	15.75+0.25 .625	10.0 - 0.5 .385	10.0 .394	7.25 .285	—	14
9277002002	2	26.5±0.7 .045	20.2±0.15 .795	10.0 - 0.5 .385	14.35 .565	7.25 .285	—	17
9277024002	3	31.4±0.6 1.237	18.5±0.15 .729	10.25 - 0.5 .394	9.4 .370	12.5 .492	26.6±0.5 1.047	18
9277008002	3	41.15±0.75 1.620	17.45±0.15 .687	11.7±0.25 .460	7.8 .307	18.65 .735	35.3±0.6 1.390	26
9277010002	3	41.15±0.75 1.620	20.5±0.25 .812	11.7±0.25 .460	10.95 .431	18.65 .735	35.3±0.6 1.390	29
9277012002	3	41.15±0.75 1.620	25.4±0.15 1.000	11.7±0.25 .460	15.75 .620	18.65 .735	35.3±0.6 1.390	34
9078014002	1	101.6±2.0 4.000	57.1±0.4 2.250	25.4±0.8 1.000	31.0 1.220	49.25 1.940	—	550

⁺ An I core, 9377024002, is available for these U cores, see page 106.

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U Cores

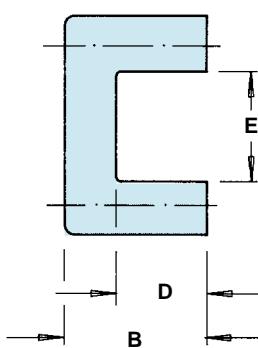


Figure 1

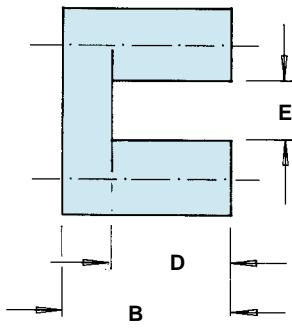
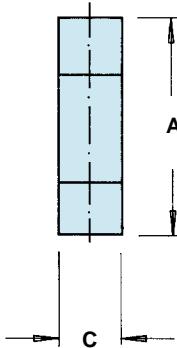
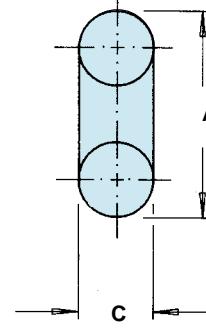


Figure 2



Symbols	Definitions
$\Sigma l/A$	Core constant
l_e	Effective path length
A_e	Effective cross-sectional area
V_e	Effective core volume
A_L	Inductance factor ($\frac{L}{N^2}$)

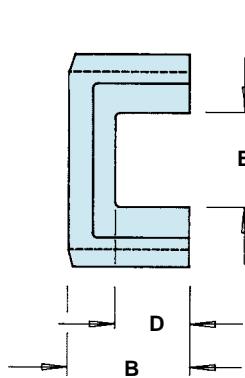
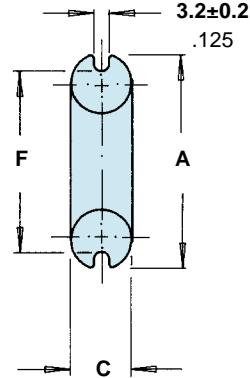


Figure 3



Magnetic Parameters

Part Number	$\Sigma l/A(\text{cm}^{-1})$	$l_e(\text{cm})$	$A_e(\text{cm}^2)$	$V_e(\text{cm}^3)$	$A_L(\text{nH}) \pm 25\%$
9077002002	16.8	2.08	.124	.257	925
9077026002	17.6	7.1	.40	2.85	1250
9077025002	20.7	8.4	.40	3.36	1050
9077024002	23.9	9.6	.40	3.88	925
9277023002	11.6	7.8	.67	5.2	1850
9277002002	13.9	9.5	.68	6.5	1575
9277024002	11.2	9.3	.83	7.7	1900
9277008002	10.5	10.3	.98	10.1	2100
9277010002	11.8	11.6	.98	11.3	1900
9277012002	13.8	13.5	.98	13.2	1675
9078014002	4.88	31.5	6.5	198	3930 Min.

E & I Cores

The E core geometry offers an economical design approach for a wide range of applications.

In a power ferrite, E cores are used in a variety of power designs. In a high permeability material they are utilized for matching and broadband transformers.

- Available materials: 77, 78, and 75.
- Part number is for a single core.
- E cores can be supplied with the center post gapped to a mechanical dimension.
- E cores can also be gapped to an A_L value. These cores will be supplied as sets.
- A_L value is measured at 1kHz, < 10 gauss.
- See section "The Effect of Direct Current on the Inductance of a Ferrite Core" on page 28 for curves of A_L vs. gap length.
- Equivalent Fair-Rite lamination sizes:

E2829	94 - - 019002	E375	9477375002
E187	94 - - 016002	E21	9477500002
E2425	94 - - 015002	E625	9477625002

Dimensions (**Bold numbers** are in millimeters, light numbers are nominal in inches.)

Part Number*	Fig.	A	B	C	D	E	F Min.	Wt (g)
94 - - 019002	1	12.7±0.25 .500	5.8 - 0.25 .224	3.45 - 0.5 .125	4.1±0.15 .161	3.3 - 0.25 .125	9.3 .365	.8
94 - - 020002	1	12.7±0.25 .500	5.8 - 0.25 .224	6.6 - 0.5 .250	4.1±0.15 .161	3.3 - 0.25 .125	9.3 .365	1.5
94 - - 016002	1	19.3±0.4 .760	8.2 - 0.25 .318	4.75±0.20 .187	5.6±0.25 .225	4.95 - 0.35 .187	14.3 .562	2.4
94 - - 012002	1	19.3±0.4 .760	8.2 - 0.25 .318	9.5±0.25 .375	5.6±0.25 .225	4.95 - 0.35 .187	14.3 .562	4.8
94 - - 015002	1	25.4±0.5 1.000	9.8 - 0.3 .380	6.6 - 0.5 .250	6.35±0.25 .255	6.6 - 0.5 .250	18.8 .740	5.4
94 - - 014002	1	25.4±0.5 1.000	9.8 - 0.3 .380	12.7±0.25 .500	6.35±0.25 .255	6.6 - 0.5 .250	18.8 .740	11
9477034002	1	25.4±0.5 1.000	16.0±0.25 .630	6.6 - 0.5 .250	12.7±0.35 .507	6.6 - 0.5 .250	18.8 .740	8.4
9477017002	1	28.0±0.6 1.102	10.6 - 0.25 .413	11.2±0.25 .440	5.6±0.25 .225	7.7±0.25 .303	19.2 .756	13
9477375002	1	34.55±0.7 1.360	14.5 - 0.25 .567	9.25±0.25 .365	9.5±0.25 .380	9.4±0.15 .370	24.8 .976	16
9477500002	1	40.75±0.8 1.604	16.5±0.15 .650	12.2±0.4 .480	10.15±0.25 .405	12.2±0.35 .480	27.8 1.095	30
9477036002	1	42.85±0.75 1.687	21.15 - 0.25 .828	15.85 - 0.75 .609	14.95±0.25 .593	11.9±0.25 .468	30.4 1.197	48
9477625002	1	47.1±0.75 1.855	19.85 - 0.4 .773	15.6±0.25 .615	12.0±0.25 .477	15.6±0.25 .615	31.6 1.245	57
93 - - 020002	2	25.4±0.6 1.000	3.3 - 0.25 .125	6.6 - 0.5 .250	—	—	—	2.7
9377024002	2	25.4±0.6 1.000	6.5 - 0.25 .250	6.6 - 0.5 .250	—	—	—	5.4
9377036002	2	42.85±0.75 1.687	6.1 - 0.25 .235	15.85 - 0.75 .609	—	—	—	21

* Insert desired material in 3rd & 4th digit positions.

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E & I Cores

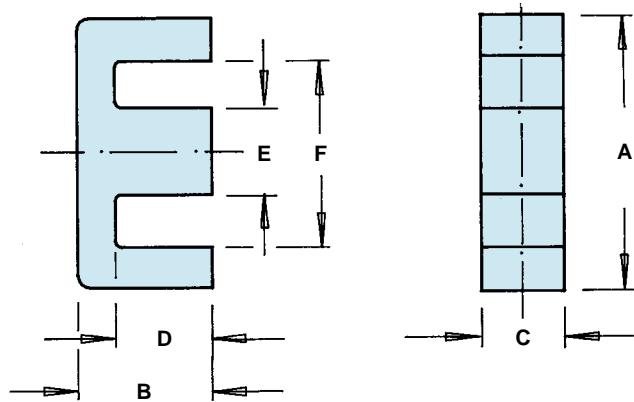


Figure 1

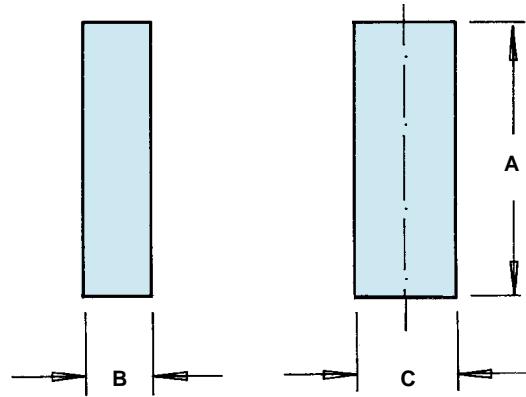


Figure 2

Symbols Definitions

$\Sigma l/A$	Core constant
l_e	Effective path length
A_e	Effective cross-sectional area
V_e	Effective core volume
A_L	Inductance factor ($\frac{l}{N^2}$)

Magnetic Parameters

Part Number*	$\Sigma l/A(\text{cm}^{-1})$	$l_e(\text{cm})$	$A_e(\text{cm}^2)$	$V_e(\text{cm}^3)$	$A_L(\text{nH})$		
					77	78	75
94 - - 019002	27.6	2.77	.101	.279	475 Min.	525 Min.	1290±25%
94 - - 020002	13.8	2.77	.202	.56	1000 Min.	1075 Min.	2600±25%
94 - - 016002	17.9	4.0	.225	.90	825 Min.	925 Min.	2300±25%
94 - - 012002	8.92	4.0	.45	1.80	1700 Min.	1900 Min.	4600±25%
94 - - 015002	12.06	4.9	.40	1.95	1300 Min.	1450 Min.	3500±25%
94 - - 014002	6.03	4.9	.80	3.92	2625 Min.	2950 Min.	7000±25%
9477034002	18.0	7.3	.40	2.98	870 Min.	—	—
9477017002	5.0	4.8	.96	4.6	3000 Min.	—	—
9477375002	7.92	6.9	.86	6.0	2050 Min.	—	—
9477500002	5.12	7.6	1.50	11.5	3225 Min.	—	—
9477036002	5.34	9.8	1.84	18.1	3175 Min.	—	—
9477625002	3.74	8.9	2.37	21.1	4500 Min.	—	—
93 - - 020002 ①	8.82	3.56	.40	1.44	1575 Min.	1725 Min.	4200±25%
9377024002** ①	8.64	3.48	.40	1.41	1700 Min.	—	—
9377036002 ②	3.68	6.8	1.84	12.5	4275 Min.	—	—

* Insert desired material in 3rd & 4th digit positions.

① ② In combination with E Cores : ① 9477015002, ② 9477036002

** May be used with U cores, see page 104.

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ETD Cores

ETD cores have been designed to make optimum use of a given volume of ferrite material for maximum throughput power, specifically for forward converter transformers. Their structure, which includes a round center post, approaches a nearly uniform cross-sectional area throughout the core and provides a winding area that minimizes winding losses.

ETD cores are used mainly in switched-mode power supplies and permit off-line designs where IEC and VDE isolation requirements must be met.

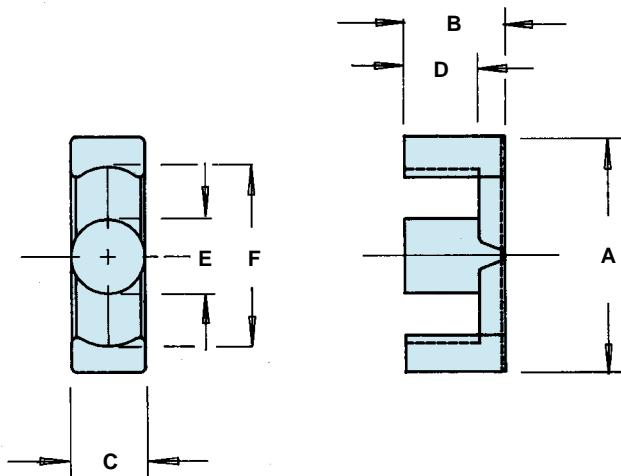
- Available materials: 77 and 78.
- Part number is for a single core.
- ETD cores can be supplied with the center post gapped to a mechanical dimension.
- ETD cores can also be gapped to an A_L value. These cores will be supplied as sets.
- A_L value is measured at 1kHz, <10 gauss.
- See section "The Effect of Direct Current on the Inductance of a Ferrite Core" on page 29 for curves of A_L vs. gap length.
- The ETD cores are in conformance with IEC 1185.

Dimensions (**Bold numbers** are in millimeters, light numbers are nominal in inches.)

Part Number*	A	B	C	D	E	F	Wt (g)
95 - - 340002	34.2±0.8 1.346	17.3±0.2 .681	10.8±0.3 .425	12.1±0.3 .476	10.8±0.3 .425	26.3±0.7 1.035	22
95 - - 390002	39.1±0.9 1.539	19.8±0.2 .780	12.5±0.3 .492	14.6±0.4 .575	12.5±0.3 .492	30.1±0.8 1.185	32
95 - - 440002	44.0±1.0 1.732	22.3±0.2 .878	14.8±0.4 .583	16.5±0.4 .650	14.8±0.4 .583	33.3±0.8 1.311	52
95 - - 490002	48.7±1.1 1.917	24.7±0.2 .972	16.3±0.4 .642	18.1±0.4 .713	16.3±0.4 .642	37.0±0.9 1.457	65

* Insert desired material in 3rd & 4th digit positions.

ETD Cores


Symbols Definitions

$\Sigma l/A$	Core constant
l_e	Effective path length
A_e	Effective cross-sectional area
V_e	Effective core volume
A_L	Inductance factor ($\frac{L}{N^2}$)

Magnetic Parameters

Part Number*	$\Sigma l/A(\text{cm}^{-1})$	$l_e(\text{cm})$	$A_e(\text{cm}^2)$	$V_e(\text{cm}^3)$	$A_{\min}(\text{cm}^2)$	$A_L(\text{nH})$	
						77	78
95 - - 340002	8.1	7.9	.97	7.6	.92	1875 Min.	2100 Min.
95 - - 390002	7.4	9.2	1.25	11.5	1.23	2100 Min.	2360 Min.
95 - - 440002	5.9	10.3	1.73	17.8	1.72	2625 Min.	2925 Min.
95 - - 490002	5.4	11.4	2.11	24.1	2.09	3000 Min.	3375 Min.

* Insert desired material in 3rd & 4th digit positions.

Bobbins

An economical and well-proven core design for many applications where relatively low but stable inductance values are required.

- Available materials: 43 and 77.
- For higher frequency designs, use a small bobbin (figure 1) in 43 material.
- For power applications, bobbins in 77 material are specified for A_L and dc bias limits.
- Assembled bobbins, shown in figure 4, can be supplied with a uniform coating of white epoxy enamel which can withstand a minimum breakdown of 1000Vrms. This coating will increase the "A", "B" and "C" dimensions and decrease the "D", "E" and "F" dimensions a maximum of **0.25mm (.010")**. The last digit of an epoxy coated bobbin is an "8". These bobbins can be supplied with notches at one end only. This changes the last digit of the part number to a "7". Bobbins of this type can also be provided epoxy coated. The last digit then becomes a "6".
- The listed dimensions are for assembled bobbins without epoxy coating.
- Bobbins are tested for A_L value at 1kHz, < 10 gauss.
- The bobbins of figure 4 can also be purchased as unassembled parts. (See pages 92 and 93).

Dimensions (**Bold numbers** are in millimeters, light numbers are nominal in inches.)

Part Number	Fig.	A 5.05 - 0.15 .196	B 2.65+0.1 .107	C 12.7±0.25 .500	D 10.0+0.3 .400	E 1.0+0.1 .042	F 0.5±0.1 .020	Wt (g)
9643001165	1	5.05 - 0.15 .196	2.65+0.1 .107	12.7±0.25 .500	10.0+0.3 .400	1.0+0.1 .042	0.5±0.1 .020	1.3
9677001165	1	5.05 - 0.15 .196	2.65+0.1 .107	12.7±0.25 .500	10.0+0.3 .400	1.0+0.1 .042	0.5±0.1 .020	1.3
9643001015	1	9.55 - 0.15 .373	4.65+0.2 .187	19.0±0.7 .750	12.7±0.15 .500	1.0+0.1 .042	1.0+0.25 .045	6.7
9677001015	1	9.55 - 0.15 .373	4.65+0.2 .187	19.0±0.7 .750	12.7±0.15 .500	1.0+0.1 .042	1.0+0.25 .045	6.7
9843000104	2	8.05±0.2 .317	5.55+0.25 .225	19.0±0.4 .750	12.7±0.25 .500	8.05±0.2 .317	2.7+0.25 .111	3.0
9877000104	2	8.05±0.2 .317	5.55+0.25 .225	19.0±0.4 .750	12.7±0.25 .500	8.05±0.2 .317	2.7+0.25 .111	3.0
9877000204	3	11.3±0.25 .445	7.5±0.25 .295	24.4±0.5 .960	17.8±0.9 .718	11.2±0.4 .440	7.25±0.25 .285	8.4
9677142009	4	14.0±0.35 .551	9.0±0.3 .354	20.0±0.7 .788	12.5±0.3 .492	3.2±0.1 .126	2.0±0.3 .079	8.5
9677182009	4	18.0±0.45 .709	11.0±0.3 .433	20.0±0.7 .788	12.5±0.3 .492	3.2±0.1 .126	2.5±0.3 .098	13
9677182209	4	18.0±0.45 .709	11.0±0.3 .433	22.0±0.7 .866	14.5±0.35 .570	3.2±0.1 .126	2.5±0.3 .098	14
9677242009	4	24.0±0.6 .945	13.0±0.3 .512	20.0±0.7 .788	12.5±0.3 .492	3.2±0.1 .126	3.0±0.3 .118	22
9677242409	4	24.0±0.6 .945	13.0±0.3 .512	24.0±0.7 .946	16.5±0.4 .650	3.2±0.1 .126	3.0±0.3 .118	24
9677282009	4	28.0±0.7 .1102	17.0±0.4 .670	20.0±0.7 .788	12.5±0.3 .492	4.2±0.15 .165	3.0±0.3 .118	33
9677282509	4	28.0±0.7 .1102	17.0±0.4 .670	25.0±0.7 .985	18.0±0.45 .708	4.2±0.15 .165	3.0±0.3 .118	38
9677352509	4	35.0±0.9 .1381	21.0±0.5 .825	25.0±0.7 .985	18.0±0.45 .708	6.9±0.4 .272	3.0±0.3 .118	56
9677353509	4	35.0±0.9 .1381	21.0±0.5 .825	35.0±0.75 .1380	28.0±0.6 .1100	6.9±0.4 .272	3.0±0.3 .118	71
9677453509	4	45.0±1.0 .1771	27.0±0.5 .1063	35.0±0.75 .1380	26.0±0.6 .1024	9.0±0.3 .354	3.6±0.3 .142	127

Bobbins

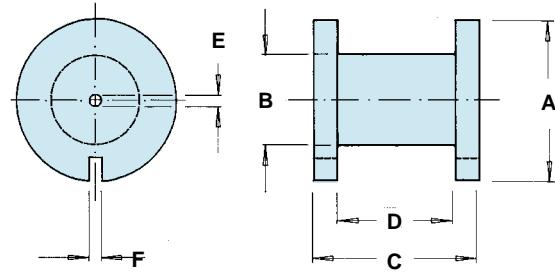


Figure 1

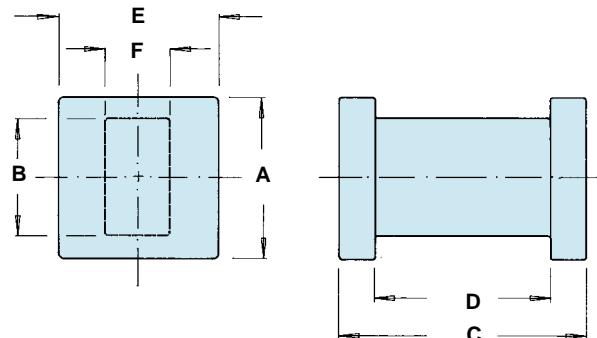


Figure 2

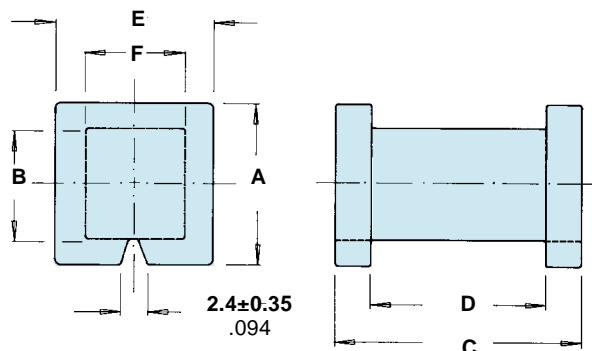


Figure 3

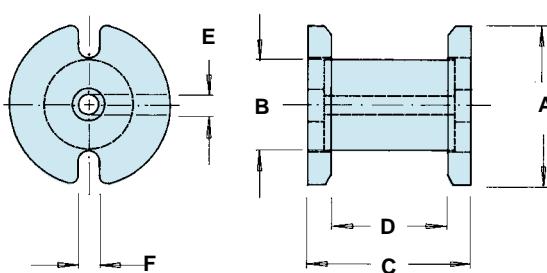


Figure 4

Symbols Definitions

A_L Inductance factor ($\frac{L}{N^2}$)
 NI Value of dc ampere-turns which reduces A_L value by a maximum of 5% at room temperature.
 A_w Winding area

Magnetic Parameters

Part Number	A_L (nH) ± 10%	NI (At)	A_w (cm ²)
9643001165	16.5	—	.12
9677001165	17	90	.12
9643001015	38	—	.30
9677001015	39	125	.30
9843000104	38	—	.33
9877000104	39	125	.33
9877000204	45	360	.37
9677142009	52	325	.31
9677182009	66	400	.44
9677182209	65	410	.51
9677242009	88	430	.69
9677242409	84	450	.91
9677282009	100	470	.69
9677282509	95	520	.99
9677352509	124	580	1.27
9677353509	110	700	1.97
9677453509	142	750	2.34

Soft Ferrite References

IEC Publications on Soft Ferrite Materials and Components

133	(1985)	Dimensions of pot-cores made of magnetic oxides and associated parts. (Third Edition).	525	(1976)	Dimensions of toroids made of magnetic oxides or iron powder. Amendment No. 1 (1980).
205	(1966)	Calculation of the effective parameters of magnetic piece parts. Amendment No. 1 (1976). Amendment No. 2 (1981).	647	(1979)	Dimensions for magnetic oxide cores intended for use in power supplies (EC cores).
205A	(1968)	First supplement.	701	(1981)	Axial lead cores made of magnetic oxides or iron powder.
205B	(1974)	Second supplement.	723:	—	Inductor and transformer cores for telecommunications.
220	(1966)	Dimensions of tubes, pins, and rods of ferromagnetic oxides.	723-1	(1982)	Part 1: Generic specification.
221	(1966)	Dimensions of screw cores made of ferromagnetic oxides. Amendment No. 2 (1976).	723-2	(1983)	Part 2: Sectional specification: Magnetic oxide cores for inductor applications.
221A	(1972)	First supplement.	723-2-1	(1983)	Part 2: Blank detail specification: Magnetic oxide cores for inductor applications. Assessment level A.
223	(1966)	Dimensions of aerial rods and slabs of ferromagnetic oxides.	723-3	(1985)	Part 3: Sectional specification: Magnetic oxide cores for broadband transformers.
223A	(1972)	First supplement.	723-3-1	(1985)	Part 3: Blank detail specification: Magnetic oxide cores for broadband transformers. Assessment levels A and B.
223B	(1977)	Second supplement.	723-4	(1987)	Part 4: Sectional specification: Magnetic oxide cores for transformers and chokes for power applications.
226	(1967)	Dimensions of cross cores (X-cores) made of ferromagnetic oxides and associated parts. Amendment No. 1 (1982).	723-4-1	(1987)	Part 4: Blank detail specification: Magnetic oxide cores for transformers and chokes for power applications - Assessment level A.
226A	(1970)	First supplement.	723-5	(1993)	Part 5: Sectional specification: Adjusters used with magnetic oxide cores for use in adjustable inductors and transformers.
367:	—	Cores for inductors and transformers for telecommunications.	723-5-1	(1993)	Part 5: Sectional specification: Adjusters used with magnetic oxide cores for use in adjustable inductors and transformers. Section 1: Blank detail specification - Assessment level A.
367-1	(1982)	Part 1: Measuring methods. (Second Edition). Amendment No. 1 (1984). Amendment No. 2 (1992).	732	(1982)	Measuring methods for cylinder cores, tube cores and screw cores of magnetic oxides.
367-2	(1974)	Part 2: Guides for the drafting of performance specifications. Amendment No. 1 (1983).	1007	(1994)	Transformers and inductors for use in electronic and telecommunication equipment - Measuring methods and test procedures. (Second Edition).
367-2A	(1976)	First supplement.	1185	(1992)	Magnetic oxide cores (ETD-cores) intended for use in power supply applications - Dimensions. Amendment No. 1 (1995).
401	(1993)	Ferrite materials - Guide on the format of data appearing in manufacturers' catalogues of transformer and inductor cores. (Second Edition).	1246	(1994)	Magnetic oxide cores (E-cores) of rectangular cross-section and associated parts - Dimensions.
424	(1973)	Guide to the specification of limits for physical imperfections of parts made from magnetic oxides.			
431	(1993)	Dimensions of square cores (RM cores) made of magnetic oxides and associated parts. (Second edition). Amendment No. 1 (1995).			
492	(1974)	Measuring methods for aerial rods.			

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- 1247** (1995) PM-cores made of magnetic oxides and associated parts - Dimensions.
- 1332** (1995) Soft ferrite material classification.
- 1596** (1995) Magnetic oxide cores (EP cores) and associated parts for use in inductors and transformers - Dimensions.
- 50(221)** (1990) Chapter 221: Magnetic materials and components.
Amendment No. 1 (1993).
International Electrotechnical Vocabulary.
(Each chapter of the vocabulary is issued as a separate booklet, each dealing with a specific field.)

The International Electrotechnical Commission (IEC) is the organization responsible for international standardization in the electrical and electronics fields. Founded in 1906, the IEC is presently composed of 51 National Committees collectively representing some 80% of the world's population that produces and consumes 95% of the electric energy.

The above publications have been issued by IEC Technical Committee No. 51: Magnetic Components and Ferrite Materials. Publications can be purchased from the American National Standards Institute, 11 West 42nd Street, New York, NY, 10036, (212) 642-4900.

MMPA Publications on Soft Ferrites

PC 110 Pot Core Standard

FTC 410 Toroid Standard

TC 200 Threaded Core Standard

UEI 310 U, E, and I Core Standard

SFG-92 Soft Ferrites, a User's Guide

The Soft Ferrite Division of the Magnetic Materials Producers Association was formed in 1973 for the purpose of enhancing communications between ferrite manufacturers and users, increasing the application knowledge of the users, establishing engineering standards, and providing a representative body for the industry.

Soft ferrite MMPA publications can be obtained from Fair-Rite Products Corp. or their representatives.

Reference Books for Soft Ferrite Applications

Ferrites for Inductors and Transformers, 1983
Snelling, E.C. and Giles, A.D., John Wiley & Sons,
New York, NY

Soft Ferrites, Properties and Applications, 2nd Edition, 1988
Snelling, E.C., Butterworths, Stoneham, MA

Transformer and Inductor Design Handbook, 1988
McLyman, Wm. T., Marcel Dekker, New York, NY

Transmission Line Transformers, 1990
Sevick, J., American Radio Relay League, Newington, CT

Soft Magnetic Materials, 1979
Boll, R., John Wiley & Sons, New York, NY

Transformers for Electronic Circuits, 2nd Edition, 1990
Grossner, N., McGraw Hill, New York, NY

Modern Ferrite Technology, 1990
Goldman, A., Van Nostrand Reinhold, New York, NY

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2643000701	65	2643173851	68	2644666611	88	2743019447	80
2643000801	65	2643200101	65	2644777711	88	2743021446*	80
2643001301	65	2643250202	65	2661000101	65	2743021447	80
2643001501	65	2643250302	65	2661000301	65	2743037446*	80
2643001601	65	2643250402	65	2661000701	65	2743037447	80
2643002201	65	2643251002	67	2661102002	66	2744040446	82
2643002402	66	2643300101	65	2661102402	66	2744041446*	80
2643003201	65	2643375002	66	2661021801	65	2744041447	80
2643004101	64	2643375102	66	2661022401	65	2744044446*	80
2643004201	64	2643480002	66	2661023801	65	2744044447	80
2643004601	64	2643480102	66	2661540002	66	2744045446*	80
2643004701	64	2643540002	66	2661540202	66	2744045447	80
2643004801	65	2643540102	66	2661665702	66	2744555577	82
2643005701	65	2643540202	66	2661666611	88	2761001111*	85
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2643023801	65	2643626102	67	2673004601	64	2761007111*	85
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* Part numbers are not listed in the tables but are identified in the italic notes.

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2773005112	85	2944666634*	88	5477180009	93	5943002701	98
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Fair-Rite Manufacturing Facilities



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▲ Wallkill, New York



◀ Springfield, Vermont